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COST-ALLOCATION FOR AUTODIN: AN ECONOMIC ANALYSIS

VOLUME I: Basic Study

William F. Beazer
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September 1977

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The theoretical basis for a usage-sensitive rate structure for DCA's AUTODIN I network is developed and applied to a simulation using sample data to develop sample rates and to assess the possible budgetary effects of implementing such a structure.

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Task 652-2

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PREFACE

The authors wish to express special appreciation to Mr. Seymour Farber, now retired, who served as DCA COTR for this study. His energy, expertise and unfailing good humor were of great help in completing the project. Dr. Harry Williams, Director of IDA's Program Analysis Division, also helped guide the project through its formative as well as creative stages.

While all of the authors contributed to all phases of the project, special credit for a major share of the analysis and writing contributions in Volume I should go to IDA consultant Professor William F. Beazer of the University of Virginia. In addition to other contributions, Dr. William Raduchel, assisted by Janet Kiernan and Lance Davidson, was responsible for the data processing tasks. Dr. John Fry served as project leader and DCA liaison.

FOREWORD

In late 1976 DCA contracted with IDA to analyze the rate structures and cost allocation procedures associated with the two primary long-haul defense communications networks, AUTODIN and AUTOVON. This study reports the results of the work on AUTODIN. The purpose of the analysis was to evaluate the current structure of rates charged by DCA for AUTODIN backbone services and, if appropriate, make recommendations about adjustments and revisions in the rate structure that might help DCA to better achieve two objectives: an equitable allocation of costs and an efficient utilization of the AUTODIN backbone.

In accomplishing the study we accepted as parameters the present size and configuration of the AUTODIN backbone as well as the procedures whereby user agencies select the services and equipment they need and contract with either DCA or the common carriers for these services. The study deals exclusively with the allocation of given costs through the process of setting rates. An extremely important question is whether or not the size of the system and its costs are, in fact, at optimal levels. This study, however, makes no attempt to broach this problem.

After an introduction and summary, we discuss the theoretical rationale for charging for access and for usage (or traffic sent), attributing to usage the characteristics of volume, distance and precedence. A model is developed for allocating costs as a function of access and usage which leads to a considerably different rate structure than that currently used. The effects of using the model on allocation of cost among

agencies and average message costs are examined using some simulation techniques and some recommendations are made and supported.

I. INTRODUCTION AND SUMMARY

AUTODIN (Automatic Digital Network) is the Defense Department's data transmission and message system. The structure and capacity of the system is determined by world-wide defense command and control requirements for certain national defense scenarios. In the absence of such requirements, the facilities are made available to government agencies for defense-related official communications and perform an important role in the day-to-day management of the armed forces and related activities.

The Defense Communications Agency (DCA) is responsible for the technical and financial management of common facilities in the AUTODIN network. Financial control is exercised through the Communications Services Industrial Fund (CSIF) managed by DCA. The CSIF is a revolving fund from which payments are made to communications common carriers and other suppliers for leased communications lines, switching equipment and other services. The fund is reimbursed by AUTODIN users from their appropriated budgets. The payments from CSIF for AUTODIN backbone services in FY 77 are expected to be about $48 million. This is to be recovered with anticipated billings to the Army for $14 million, Navy for $11 million, Air Force for $17 million, with other DoD and non-DoD agencies supplying the remaining $6 million.

Under the current system of allocating AUTODIN costs, the various agencies are required to estimate their AUTODIN needs in terms of the number of connections of various speeds (from 75 to 4800 baud) by months of use for the coming budget year. On the basis of these user estimates and projected costs for switch and trunk leases and O&M costs, DCA computes connectivity

charges that are designed to cover its anticipated industrial fund payouts for AUTODIN backbone costs. The connectivity fees are calculated as a function of the *projected* number of connections for each agency but billing is for the *actual* number of connections. Since actual connections are usually fewer than projected, there is typically a shortfall in DCA revenues to the CSIF.

On the basis of an analysis of the economic, technical and managerial aspects of the AUTODIN I system, this study concludes that the current method for allocating backbone costs among users does not meet the criteria of equity and efficiency and that it has perverse incentive effects. A system incorporating other principles of cost allocation is recommended. In the following chapters, the rationale and structure of such a system are developed. A rate algorithm and a computer simulation embodying it are provided and the application of the principles to the future AUTODIN II system is discussed.

In the process of the analysis it became apparent that a backbone rate system involving cost incentives cannot answer all the problems of managing AUTODIN which face DCA and its user agencies. Efficiency in communications cannot be guaranteed by a rate structure; reinforcing administrative action and policy decisions are required. It is beyond the scope of this study to recommend particular policies to supplement the proposed rate system. Some policy alternatives are identified, however.

The selection of a system for allocating costs involves a number of sophisticated trade-offs. In one sense, AUTODIN I is like an economist's public good. There is no cost to the network for one more message or for one more access line--at least at this time. Capacity is determined by command decision to meet military requirements and these potential needs greatly exceed current demand. Since capacity exists to accommodate

more messages and lines, the objective of the U.S. Government should be to ensure that as much traffic as possible is placed through AUTODIN I. If an individual user should find that a commercial service is cheaper for some particular application (although this seems highly unlikely given any reasonable rate structure), it is still more expensive for the agency to use that service, since the AUTODIN I costs must be paid in any event.

Any rate structure must be perceived as fair by the agencies--this is not commercial marketing but cost-sharing. Efficiency versus equity is an old dilemma in economics, and a final pricing structure will require some policy decisions by DCA. However, seven conclusions can be reached at this time.

- Efficient use of the system requires that users choose both the appropriate number and speed of access lines. Placing all charges on connectivity weighted by speed obviously provides very strong incentives to choose the lowest feasible speed and to minimize the number of access lines. A zero access charge, however, could lead to more demand for high-speed lines than the system could handle. Thus, initially, at least, a connectivity charge should continue to be assessed but at a considerably lower level than at present. The access charges considered in the study would collect in the aggregate approximately 20 percent of the total system costs.

- The majority of revenue should be collected on the basis of usage. There are two units in which usage can be measured, messages and line blocks. The choice between them is a matter of judgment but a combination of fixed fee per message plus a charge per line block seems reasonable.

- The costs of long-distance service benefit long distance users. Others can be excluded from these benefits. Therefore, long distance costs (trunks and associated access lines) should be charged to long distance users. The payment for long distance should be collected through usage fees, not connectivity.

- A surcharge should be collected on FLASH messages. Use of precedence interrupts and delays other messages and these costs should be paid by the FLASH user. The surcharge can be either a lump sum per message or an additional cost per line block. The latter would provide

an incentive to keep FLASH messages short. The former would recognize that the mere fact of interruption imposes a cost, regardless of the lengths of the FLASH message.

- Rate setting and billing should be coordinated to limit CSIF deficits. We recommend that efforts be made to develop better forecasts of system use so that the rates can be set on the basis of more accurate projections than are currently used. We also recommend that billing be done on the basis of actual costs rather than projected costs.
- DCA should address the issue of acquisition and configuration of off-system equipment and services. It may be that new policy decisions either by DCA or others in the DoD will be required to assure efficient integration of AUTODIN with other communications activities. Attempting to solve all problems with prices alone may not be successful.
- An integrated charging system should be developed for AUTODIN to include both AUTODIN I and AUTODIN II when in place. This pricing should recognize the interdependency of the two systems. We further recommend that consideration be given to implementing procedures to permit charges in AUTODIN II both for distance and precedence.

Some of the effects of switching from a rate structure in which all revenue is derived from connectivity fees to one in which 80 percent of other revenue is collected through charges on line blocks are illustrated on the following tables.[1] Table 1 compares the current rate structure to a proposed hypothetical rate structure.

If the proposed rates were adopted, the share of total budget paid by each agency would change, with the share rising for agencies with higher than average usage and fewer than average line connections without identifying the agencies. Table 2 indicates how the shares of major users might be expected to shift.[2]

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[1] The tables are based on FY 76 levels of estimated message traffic and FY 78 backbone costs.

[2] An "agency" is a group of similar PDC account numbers.

Table 1. SUBSCRIBER RATES

Current (100 Percent Connectivity) and Proposed (80 Percent Usage) Systems

Current Rate Structure		Potential Rate Structure	
Connectivity Charges:	$/Month	Connectivity Charges:	$/Month
Low Speed	$1,624	Low Speed	$ 279
Medium Speed	4,873	Medium Speed	837
High Speed	7,580	High Speed	1,302
Line Block Rates:	¢/line block	Line Block Rates:	¢/line block
Local	0	Local	0.86
Area	0	Area	0.90
Inter-Area	0	Inter-Area	0.99

Table 2. PERCENT OF TOTAL BACKBONE COST PAID BY "AGENCIES" UNDER TWO RATE STRUCTURES

Agency		Present 100 Percent Connectivity Rates	Proposed 80 Percent Usage Rates
Three	A	30.5	27.7
Highest	B	16.9	14.1
	C	20.6	19.6
Second Three		15.1	23.2
All Others		16.9	15.4

Another interesting comparison is that between what a subscriber might be paying for AUTODIN services and what he would have to pay for an equivalent amount of commercial communications. These figures are shown in Table 3.

Table 3. COMPARATIVE MONTHLY COSTS FOR A "TYPICAL"[a] AUTODIN I SUBSCRIBER

	AUTODIN I Revised Rate Structure (80 Percent Usage)	Commercial Equivalent
CONUS Messages	$175/month	$ 954/month (Mailgram)
Overseas Messages	249/month	1,367/month (International Telex)
Total	$424/month	$2,321/month

[a]Low-speed access line at $279/month, 292 domestic messages @ 14 line blocks, 239 overseas messages @ 21 line blocks.

II. A MODEL FOR ALLOCATING AUTODIN COSTS

A. SYSTEM CHARACTERISTICS RELEVANT TO RATE-MAKING

AUTODIN I is one of a number of communications networks maintained or supervised by DCA. It is a secure, store-and-forward computer-based message processing system composed of a number of switches linked by high-speed trunk lines.[1] Users are continuously connected to each switch as a telephone is always connected to its exchange. The current 1300 users range from slow-speed teletype terminals to computers.

The AUTODIN I user enters a message with one or more destinations into its switch. The switch accepts the message in its entirety, logs it and stores it. In accordance with requested priorities, the switch then transmits the message to the destinations as circuits become available. Once the user has entered the message, it is the responsibility of the host switch to make delivery. Refile centers are used to enter messages into commercial channels for non-AUTODIN destinations.

The AUTODIN switch is a computer which processes messages according to programmed conventions. The CONUS switches leased from commercial firms are capable of storing messages for forwarding in drum, disk and tape secondary memories. The magnetic core data memory of the Accumulation and Distribution Unit (ADU) is (in present configuration) the first capacity limit on the system. This unit interfaces between the central processing unit (CPU) of the switch and incoming and outgoing channels.

[1] Currently 17 switches and 41 truck lines.

This is necessary because incoming and outgoing transmissions are at different rates. When a message comes into the switch from a tributary user, it is stored in ADU data memory until the CPU sends it on. When the CPU transmits the message to another switch, the receiving ADU data memory stores the information received from the originating CPU in order that further transmission can be accomplished at a speed compatible to that of the receiving subscriber's equipment.

Because the magnetic core storage elements are scanned at a fixed rate and because the CPU operates at internal speeds faster than sending or receiving subscriber equipment, differing amounts of ADU data memory are required for differing speed access lines. At present, all leased switches are configured with ADU data memory capacity of approximately 2340 line blocks. The current protocols assign up to 6 line blocks of memory to all low-speed channels (75, 150, and 300 baud), up to 18 line blocks to medium-speed (600 and 1200), and up to 28 line blocks to high-speed channels (2400 and 4800 baud). The amount of memory absorbed by low-, medium-, and high-speed lines is thus in the ratio of 3 to 9 to 14. These ratios are used in the calculation of connectivity fees. The leased switches can accommodate 250 trunk or subscriber channel connections,[1] but 83 high-speed connections or 130 medium-speed connections would exhaust the ADU memory capacity.

Although the vast majority of the messages are narrative traffic, bulk computer-to-computer transmission constitutes a rapidly growing share of total volume. Plans exist for a second network, AUTODIN II, to complement and to some extent

[1]The eight government-owned switches in Europe and the Pacific operate somewhat differently, utilizing a dynamic assignment procedure employing Line Traffic Coordinator processor units to interface input-output channels and central processing elements within the switch. These switches can accommodate 100 to 200 access lines, including trunks, depending on how they are configured.

replace AUTODIN I. AUTODIN II is a packet-switching network designed for computer-to-computer communication. Packet-switching involves high-speed switch-to-switch transmission at 50,000 bits per second. Messages are broken up into "packets," each of which is transmitted separately by whatever route is available to the addressed switch and terminal. Packet-switching requires that a direct logical connection between sender and addressee exist for a packet to be dispatched; unlike the message route with circuit switching, however, the specific path may vary from packet to packet. The system permits the maximum use of the capacity of multiple-channel high-speed trunks. When AUTODIN II becomes operational, a substantial portion of AUTODIN I users will be connected. Eventually the AUTODIN I switches will become service centers interconnected by AUTODIN II.

DCA is responsible for AUTODIN I network management but the equipment in the United States, including Hawaii (nine of the 17 current switches), is leased from Western Union, as are some of the trunk lines (the others are leased from other carriers). DCA must pay for the equipment and services annually. It does so from its industrial fund which in turn receives payments from the using agencies.

The Communications Services Industrial Fund, out of which AUTODIN, AUTOVON, and other communications services are paid, is a revolving fund, replenished by transfers from the customer agency appropriations. DCA acts as the agent for various DoD-related units of the Federal government in paying for leased communications services. In FY 77, over $390 million will have been paid for communications services. Of the $390 million, $48 million will have been for AUTODIN backbone costs.[1]

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[1]Appendix D gives detailed breakdowns of backbone costs for recent years.

B. CURRENT PRACTICES

AUTODIN costs currently are allocated exclusively on the basis of charges for "connectivity." DCA bills each user monthly for the number of access lines (connections to AUTODIN switches) he has in place. There are three different charges, depending upon the speed of service. Slow-speed users, who connect with equipment transmitting at either 75, 150, or 300 bits per second, are charged the lowest monthly rate. Medium-speed users with 600-1200 bits per second or greater pay the highest monthly rate. The three rates are in the ratio of 3 to 9 to 14. These ratios derive from the technical characteristics of the first constraint on switch capacity, the ADU memory.[1]

Users are requested to project the number of access lines of various speeds that they expect to require over a twelve-month period. DCA then converts these projections of access line requirements into an equivalent number of "weighted units." A high-speed line for one month is equal to fourteen weighted units, a medium-speed is nine and a slow-speed is three.

Once the total number of weighted units is arrived at, it is divided into the projected backbone cost to obtain a monthly cost per weighted unit. This cost is then multiplied by three to arrive at the monthly charge for a slow-speed line, by nine for the medium-speed charge, and by fourteen for the high-speed charge.[2] The total cost for an agency is calculated

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[1]This assumes a Western Union leased switch with eight quadrants of memory. Other limiting factors on switch capacity are the number of access lines (its access line termination and trunk terminations) and trunk terminations at 250 per switch and the throughput limit of approximately 250,000 baud.

[2]The procedure for calculating rates requires first the computation of the number of "weighted units" implied by service plans. The estimated total backbone cost is divided by total weighted units to derive a "weighted unit cost," then the weighted unit cost is multiplied (continued on next page)

on the basis of the *actual*, as opposed to projected, number of lines of each speed the agency has in place during each month.

Since the actual number of lines invariably differs from the projections, so too does the amount of money collected by DCA differ from the actual backbone costs. Any shortfall or surplus for one year is added to or subtracted from the estimated costs of the next budget year before a new set of line charges are calculated. Currently, no charges are levied for usage, distance or precedence.

In the following discussion, we examine the rationale for and implications of a substantial change in the current method of allocating backbone costs. A model for allocating costs on the basis of usage, distance, and precedence, as well as connectivity, is developed and tested.

C. CONNECTIVITY CHARGES VS. USE CHARGES--A THEORETICAL DISCUSSION

AUTODIN capacity is determined by potential defense contingencies and is sufficient to accommodate both more access

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(contd) by 3, 9, and 14 respectively to arrive at the connectivity fee for slow-, medium-, and high-speed lines. The weighted unit cost is calculated as follows:

Let B = annual backbone cost in dollars

S = quantity of slow-speed connections (in months connected x connections) (weight = 3)

M = quantity of medium-speed connections (weight = 9)

H = quantity of high-speed connections (weight = 14)

W = weighted unit cost in dollars per month

$$W = \frac{B}{3S + 9M + 14H} \cdot$$

3W = slow-speed connectivity fee

9W = medium-speed connectivity fee

14W = high-speed connectivity fee

lines and more traffic than at present. Backbone costs are largely fixed and would not be changed by adding or subtracting relatively large numbers of subscribers. As a result, the question we wish to examine is only indirectly one of pricing services. The main objective is to find an equitable and efficient method for allocating costs. The pricing process is one means to this end. The goals to be achieved are maximum utilization of AUTODIN, the creation of incentives for users to make the most efficient choices in acquisition and use of auxiliary equipment and in the employment of personnel, and the achievement of an appropriate degree of equity in the allocation of costs among all users.[1]

If all users had identical demand schedules and no non-backbone auxiliary equipment were required, costs could efficiently be allocated by having a fixed charge for usage--i.e., the appropriate pricing would be much the same as currently exists. However, when demand schedules differ and other equipment is required, such a pricing system can lead to inefficient resource allocation. Some customers will attempt to avoid the single, relatively high, fixed charge for access and in the process pay for equipment, resources, and alternative services that, from an overall point of view, are redundant.

Before examining the system as it actually exists and making particular recommendations about cost allocation, we shall discuss from a more theoretical point of view some of its economic characteristics. The most important characteristics flow from the fact that the size and total costs of the AUTODIN backbone are fixed and virtually independent either of the number of access lines or of usage.[2] This has two

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[1] In the accepted terminology, a "user" is one of the services or an agency. When referring to individuals or offices actually sending messages, we shall apply the term "direct user."

[2] As we shall see later, the memory capacity of the switches could be exceeded if all lines were made high speed.

implications. First, the current marginal cost of carrying an additional message is zero; second, the current marginal cost of an additional hook-up is zero. (We emphasize that we are talking only about backbone costs, not the cost of having access lines.) If one were to observe the classical economic dictum of setting price equal to marginal cost, there would be no charge for either access or messages. And yet the costs of the system must somehow be allocated to the users.

In a sense, the current system is very much like a classic public good. Usage by one person does not preclude another from using it. The economic theory concerning the allocation of public goods implies that people should be charged a lump sum according to how much they value the good itself. Such a valuation for AUTODIN is impossible to obtain, of course, but the most efficient kind of pricing system would be one which closely approximated it. In fact, this is the way in which we shall define "equity"--that pricing structure is most equitable which most nearly allocates costs on the basis of what appears to be the user's valuation of the services he receives.

There are basically two methods for allocating the costs of AUTODIN service. One is to charge for access; the other is to charge for use. Choosing one or the other of these two methods in its pure form could lead to user behavior different from the optimal, "optimal" being defined as that which would occur if each was asked to place his own value on the service and then select his own equipment and amount of use. The question is--what pricing policies are likely to result in the least deviation from this optimum?

Any user making a decision on how many access lines to acquire and what mix of equipment, people, and media to use in performing his communications activities will seek to minimize his own budget. His primary concern is the cost he has to pay, not the overall cost to the DoD. The higher the charge for each access line to an AUTODIN switch, the more attractive

become alternatives that permit the user to reduce the number of access lines he contracts for. For example, if the cost of an AUTODIN connection is high relative to the cost of leasing lines from commercial communications companies, he may attempt to cut costs by leasing only one AUTODIN line and creating a message center which receives and transmits all messages and is connected to the actual origination and reception points by a network of commercial lines or by some other form of communications.[1] By the same token, a high access cost could induce a user to acquire less capacity than his peak load requirement. Part of the peak load would then be allocated to other, more costly (in real terms) communications methods. In both cases, the total communications costs would be higher, although each user individually would believe he is minimizing his own costs.

Thus, the lower the access costs, the less distortion there will be in selecting equipment, personnel, and alternative modes of communication. At the limit, if the connectivity fee were zero, the user would have no incentive to choose a communications system that minimized his access to the backbone while increasing his other costs.

Let us now consider the incentive effects of allocating costs as a function of usage. This could be accomplished by charging for messages, or line blocks, or both. Ordinarily, individuals or entities faced with a positive cost for a good or service will use that good up to the point where its marginal value is equal to the price they pay. It could be that AUTODIN users would behave the same way. Since the current marginal cost of an additional message on AUTODIN is zero, charging a positive price could create distortions in that users would send fewer AUTODIN messages than they really should,

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[1]There are limits to this process. Access through another switchboard can be inconvenient, especially if all users are not under the same managerial authority.

from an economic point of view.[1] They would either not send as many total messages as otherwise or they would turn to other, superficially cheaper but less efficient alternatives such as ordinary mail.

We thus find ourselves in the position of saying that theoretically to achieve an optimal configuration of equipment, the access costs should be zero, and to achieve optimal usage of the system, the usage charges should be zero. But the costs must be allocated and so we cannot have both zero access and a zero usage charge. We are left with a choice between two alternatives, both of which can lead to a misallocation of resources. Recognizing that some distortion is almost inevitable, our objective then becomes to choose a pricing structure combined with administrative procedures which will minimize overall distortion and produce the desired communications services at the least total cost. We think such a structure is possible to achieve. The solution lies in pricing for both usage and access, making sure that actual message senders are not given an incentive to reduce the number of messages they send. At the same time, the people who make decisions on equipment purchase and system configuration should be confronted with prices for access lines that lead to optimal choices of equipment and personnel.

Applying this pricing rule for access lines means that the cost of access should be low enough that a user will not have an incentive to purchase equipment or use services which would increase the overall cost of communications activities relative to what it would be if all equipment decisions were made by a central decision-maker. Following this dictum to the letter may call for access costs to be zero. As we shall see later, however, there are legitimate reasons why the

[1]Of course, the degree of distortion will depend upon the elasticity of demand which is not likely to be very high for AUTODIN users.

connectivity fee should not be eliminated completely. We merely wish to emphasize here that it should be as low as possible subject to other constraints.

Of course, the lower the access charge, the greater will be the fraction of costs allocated according to usage. The cost per line block or message unit will go up. We have already argued, however, that charging by usage is the more appropriate way to allocate costs equitably. In addition, it is unlikely that a usage charge will result in significant deviation from optimal utilization of the system.

Decisions governing usage are made at a much lower level than decisions on access lines. The people who actually write messages and decide how many to send and by what medium are not the ones who make the decisions on budgets. The direct users pay no bills and have no reason to limit their use or respond to any kind of pricing system unless directed to do so by superiors.[1]

It appears then that there are compelling reasons for believing that allocating costs primarily on the basis of usage rather than access would lead both to a more "equitable" distribution of costs and to a maximum efficiency of system use. To return to our public good analogy and define "equitability" in terms of a value to a user, actual usage is the only practical measure of what the system is worth to a subscriber.[2] Large usage implies he is getting much benefit from it; small usage the reverse. With regard to efficiency, a low access cost would permit the user to choose his equipment and personnel

[1]Since the marginal costs are negligible, superiors should be educated to encourage usage rather than curtail it.

[2]It is possible, of course, that a user would place a very high value on the first few messages he sends and relatively low marginal values on the remainder, but there is no way to estimate such differences. As a result, the number of messages is the best observable indicator of the value of the service.

configurations primarily on the basis of real economic costs. Allocating cost among agencies according to use, while at the same time encouraging direct users to behave as though the services are free, would encourage the substitution of AUTODIN for any other communications whose real costs exceed the marginal cost of AUTODIN.

We have thus far dealt with an abstract, simplified version of the AUTODIN system. We have made no reference to transmission speed, area coverage, precedence, or choice of units in which to measure usage. We shall now consider these in order, with emphasis on transmission speed and distance as these will exert the most influence on the application of the simple rules proposed above.

D. CHARACTERISTICS OF THE COST ALLOCATION SYSTEM

1. Transmission Speed and Access Charges

Transmission speed is a characteristic of service that is currently one determinant of the access cost for AUTODIN users. Before we can make a recommendation as to whether or not it should remain a determinant, we should examine whether charges for speed are necessary for the achievement of the objectives of equity and efficiency. There are three categories--high, medium, and low--into which are grouped the various transmission speeds. The access charges for these three categories are related to each other in the ratios of 3:9:14 with the charge for the low speed having three times the basic rate for a "weighted unit." These ratios reflect the maximum amount of ADU memory assigned to lines of the different speed classes.

If costs are allocated purely on the basis of access to the system, it could be argued that differentiation by speed accomplishes to a certain extent the equity objective we have established. The people who require a higher transmission speed are presumably the people who have more data to transmit.

Thus, allocating costs according to transmission speed is from one point of view an imperfect substitute for allocating costs according to usage. We say "imperfect" because charging for access requires that people be put into one of three discrete groups. As a result, usage within a single group could vary considerably even though all members pay the same amount.

Allocating costs on the basis of usage, on the other hand, accomplishes with more precision what charging for speed accomplishes so imperfectly. Those individuals making greater use of the system would automatically pay a larger portion of its costs. Moreover, the allocation of costs would be along a continuum rather than into three discrete boxes and thus would reflect more closely the value of the service to the individual user.

An efficiency problem arises, however, if access speed is not charged for. ADU memory capacity at the switch is more limited than transmission capacity, and the higher the speed of access, the more of this memory capacity is absorbed. Although there is currently unused capacity in the system, ADU memory is not sufficient to permit every line to be 4800 baud.[1] As a result, there is definitely a rationale for having charges to induce those who do not need high speed to continue using low and medium speed lines.

The appropriate level for such charges is somewhat debatable and there seems to be no single operational rule one can recommend. It is possible, however, to define some theoretical upper and lower bounds to the charges that should be levied. The lower bound is nothing more than the price at which all line capacity is absorbed. This can be illustrated in Figure 1. The units on the quantity axis are *weighted units* while the vertical axis measures their price to the user. The line D is the demand for line connections to the backbone and Q_o is the total capacity.

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[1]Making every line 4800 baud would require 3500 line blocks of ADU memory per switch; the current capacity is approximately 2340.

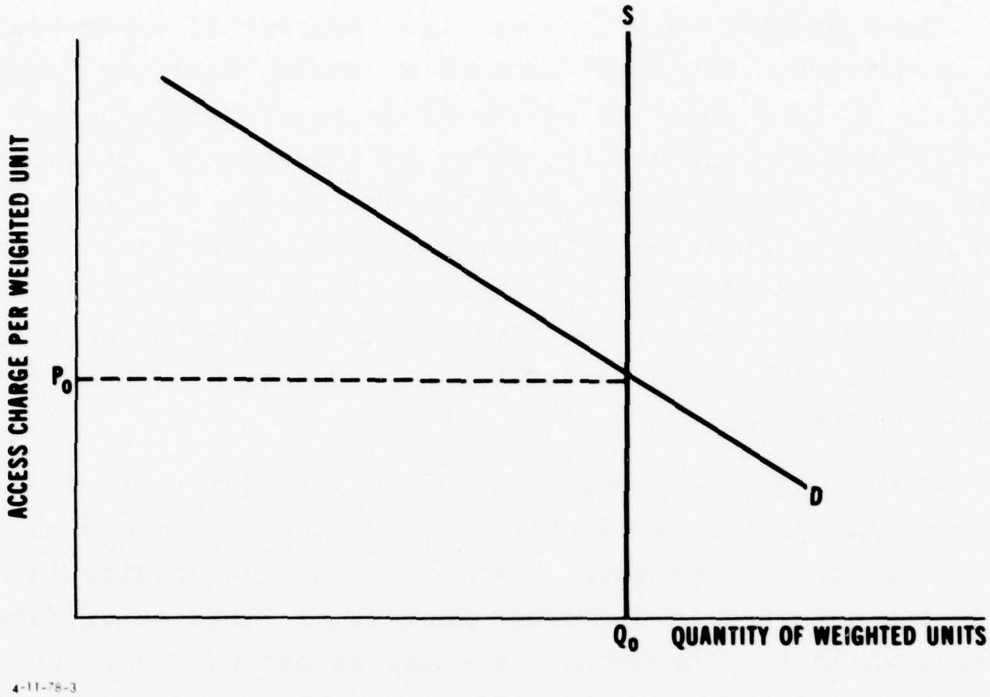

Figure 1. NOTIONAL DEMAND FOR AUTODIN SERVICE

Demand would increase as price fell not only because more lines would be connected but because the price differentials between different speed lines would fall as well and users would substitute higher for lower speeds. The access price which just allocated total line capacity Q_o would be P_o and is the lower limit for access costs.[1] This lower limit must, for the time being, remain a theoretical concept since there are insufficient data upon which to base an estimate of P_o.[2]

[1]A decision to allocate total line capacity may seem to contradict the idea that national security requires unused capacity in order to satisfy potential demand during a war. Presumably, however, the requirement for unused capacity would be primarily for throughput rather than connectivity. If some amount of excess capacity were required, we could simply define Q_o as being the total less the projected excess requirement.

[2]It is not impossible that P_o should be zero if at a zero price all memory capacity is *not* absorbed.

There are two ways in which the theoretical upper bound can be defined. The first concept we shall label the "cost limit." It is a function of the division of switch costs between that for ADU memory, which is absorbed by line connections, and that for other switch capabilities. The second concept, which we shall call the "efficiency limit," is determined by the alternative kinds of communications services from among which users may choose. We first shall examine the cost limit and discuss how it can be derived as a function of the allocation of switch costs.

As discussed earlier, each switch in DIN I performs two fundamental functions. It temporarily stores messages in its ADU memory and it transmits them. The memory capacity is set aside and absorbed in different amounts by lines of different speeds, while the throughput capacity is absorbed only by size of message and is independent of access line speed--all trunk transmission occurring at the same speed. Theoretically, one can conceive of a switch as being a simple mechanism composed of two components, a memory and a transmitter. One then could obtain figures for the lease costs of each component and allocate the memory costs by charging for access, and the transmission costs by charging for usage.

In reality, precision either in defining equipment by function or in measuring the lease cost of memory is impossible to achieve. Much of the equipment serves both functions. Estimates we have obtained, however, indicate that of the FY 76 $3.5 million monthly cost for DIN I switches, $750,000-850,000 can be assigned to ADU's, the memory buffers being the constraining element. Thus, ADU memory cost is approximately 20-23 percent of the total lease cost. If we assume that O&M costs are associated with memory and non-memory equipment in approximately the same ratio, then 23 percent of total

switch costs is a rough measure of the upper limit of costs that should be recovered through charging for access.[1]

The alternative upper bound--the efficiency limit--is based on efficiency considerations and depends upon the alternatives open to users. With high connectivity fees, users have an incentive to minimize access to the backbone and satisfy communications requirements by building up networks behind their own message processing equipment. The overall cost to the government of creating such networks is more than the cost of providing similar service through AUTODIN. Access charges thus should be low enough so that these kinds of alternative network buildings become more costly than adding access lines. Determining what this level is may be difficult, perhaps impossible except through experimentation.[2]

One of the upper limits we have discussed can be binding. The other will be redundant. If the efficiency limit is below the cost limit, it should be the upper bound on the ratio between costs collected by access charges and total costs. Otherwise, even though only a fraction of total costs are collected through access fees, these will still be incentives to expand off net services. Perhaps the relationships among the cost limit, the efficiency limit, and lower limit, P_o, can be illustrated best with another diagram similar to Figure 1, relating access charge to the quantity of weighted units demanded by users.

In Figure 2, Q_o is the supply of line connections; D is the demand; P_o is the access charge which exactly allocates capacity; P_c is the cost limit, it is determined by the ratio of memory cost to total cost; and P_e is the efficiency limit. Above this level, users begin to find it attractive to reduce the number of

[1]This also may be a lower limit for a practical initial charge, as DCA must approach the optimal access charge from above, i.e., by successive price reductions.

[2]Some information might be obtained from talking to users about their own system designs.

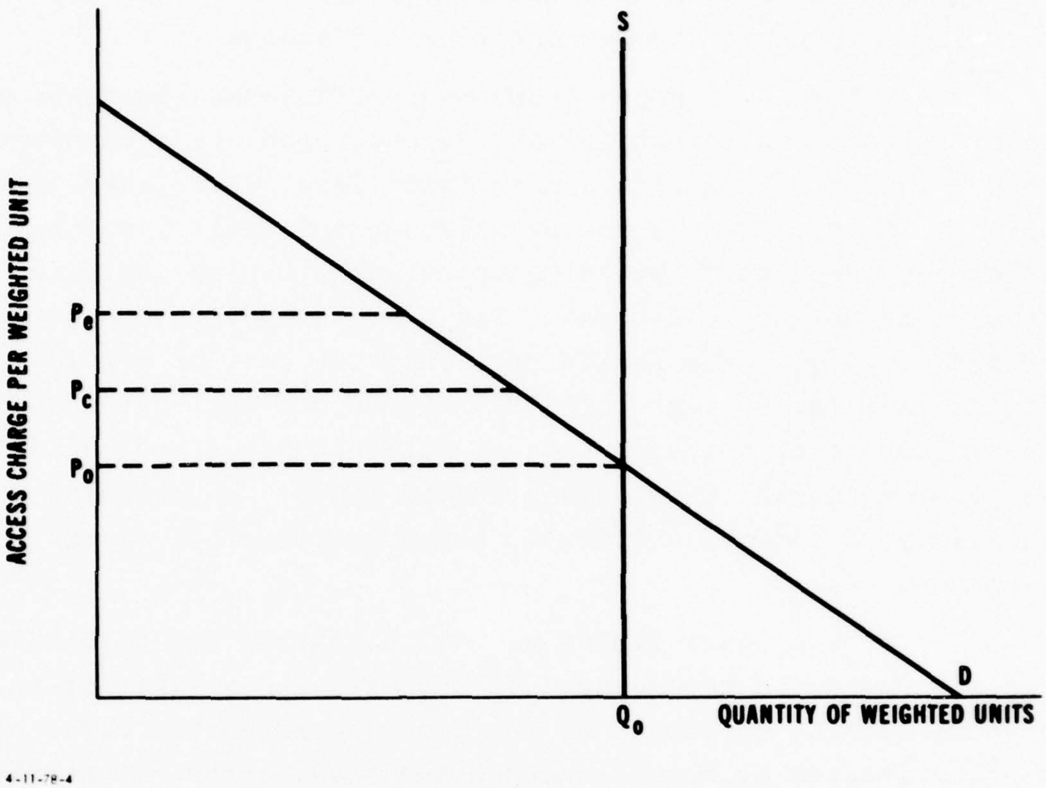

Figure 2. THEORETICAL UPPER AND LOWER BOUNDS ON CONNECTIVITY CHARGES

access lines and assemble their own networks behind a switchboard. Since previous experience is not sufficient to define the demand curve, we have no information about its slope or the relationships among our three prices. For the sake of illustration, however, we have postulated that the cost limit is below that efficiency limit. Thus, the efficiency limit is redundant and the cost limit determines the upper bound for the connectivity fee. Any charge between P_c and P_o is acceptable from an economic point of view. The choice will affect two things--the amount of unused memory capacity at switches and the allocation of costs among users.[1] In what follows we use the cost limit

[1]We should mention again that P_o could be zero. Although it is unlikely, it is also possible that P_o lies above P_c.

in estimating the appropriate charges to be applied to access and to usage. Experience with such an allocation of costs may well indicate that it is desirable to lower the access charge still further.

2. Distance Charges

Currently, access to AUTODIN confers with it the ability to send messages to any point within the system. Allocating operating costs by charging for use would permit higher fees to be assessed for long distance messages than for local ones. The rationale for charging for distance can be illustrated by considering a very simple hypothetical AUTODIN system. Consider an AUTODIN communications system with just three switches, none of which is connected to any other. Assume that the ADU memory of each is fully used, but that more traffic can be transmitted. (This is almost inevitably the usual situation given the relationship between transmission capacity and access capacity for a switch.) The costs for each switch would be borne by the individual users of each switch.

Now, suppose that some (but not all) users at each switch want to communicate with users at other switches, so trunks are added which connect all three switches. Trunks require ADU memory just as do access lines. Since we have assumed all memory capacity is allocated, either some users must be disconnected from the switches in order to make room for the trunks (4800 baud), or additional memory capacity must be purchased to permit the trunks to be connected without eliminating users. We shall assume the latter so that the total cost of the system rises by both the cost of leasing trunks and the cost of increasing the memory at the switches. If the throughput capacity of all switches is still sufficient to handle all traffic, both

local and long distance,[1] then these memory and trunk costs represent the total increased cost of operating the expanded system. These costs should clearly be borne by the users who send messages between switches.

If the key assumption that we have used is a correct one, i.e., that the throughput capacity of switches need not be increased in order to handle the volume of long distance messages, then we now have a defensible methodology to apply to the total system for calculating a local message unit rate and long distance rates. To illustrate the methodology, we shall assume there is only one long distance message area.

The cost of linking terminals, i.e., trunks and the memory capacity they absorb, should be allocated to long distance users in proportion to the number of messages they send. The backbone costs, exclusive of trunks and memory capacity required for their hookup, should be allocated to everyone as a function of both connectivity and usage.[2]

Those relations can be expressed as a simple mathematical model. Define the following symbols:

S = total annual cost of switches (total backbone exclusive of trunks)

R = total costs allocated by connectivity (total annual cost of memory)

a = ratio of memory used for trunks to total memory available

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[1]"Local" AUTODIN traffic is that which is routed between subscribers served by the same switch, thus utilizing neither interswitch trunks nor switching center facilities at another switch. Long-distance traffic involves a sender and receiver not "homed" [connected] to the same switch. At a minimum, one other switch and an interswitch trunk line would be used to complete the transmission.

[2]Throughout the following discussion we make the implicit assumption that the allocation of cost between connectivity and usage is on the basis of memory cost rather than in terms of the opportunity cost of users. In other words, all are using the "cost limit" rather than the "efficiency limit" discussed in Section III.C. This assumption is not necessary.

x = single switch messages

y = long distance messages

T = annual trunk leasing cost.

Then the cost per message unit for single switch messages should be the cost of switches less the costs allocated to connectivity:

$$\text{(A)} \qquad C_1 = \frac{S - R}{x + y}$$

The cost per message unit for long distance messages should include the cost of using a single switch, plus the trunk cost and fraction of memory capacity used by the trunks:

$$\text{(B)} \qquad C_2 = \frac{S - R}{x + y} + \frac{aR + T}{y}$$

Equations (A) and (B) also illustrate the difference in allocation of switch costs between the situation with only local capability and that with long distance. Since y is the increase in messages, the per message cost with only local capability would be:

$$\text{(A}'\text{)} \qquad C_1' = \frac{S - R}{x}$$

Since $C_1 < C_1'$, the average cost per message unit (ignoring the trunk and new memory charges) will fall when switches are connected and those using only one switch will pay less in total for their messages than they did before switches were linked. Those using the long distance service will pay more of the original system cost because they are sending more messages. In addition, they will be sharing among themselves the cost of creating a linked network from the isolated switches.

In the example we have discussed only two classes of messages--local and long distance. In reality it is possible to divide messages into three distance classes: *local*, which enter and leave through a single switch; *area*, which enter one switch, pass over at least one trunk and exit at another switch within

the same geographic area (such as CONUS or Europe); and *inter-area* which originate in one area, pass through an overseas cable, and terminate in another area.

3. Precedence

Precedence is another characteristic that must be considered in establishing a rate structure for allocating costs. There are effectively two precedence levels for AUTODIN--FLASH, and all others. On AUTODIN I, FLASH messages always interrupt any other precedence.

It makes sense from an economic and resource allocation viewpoint to charge for FLASH on the basis of usage rather than capability. Assessing a fixed fee for capability means that there are no incentives whatever for a user to limit his use of the FLASH precedence. As a result, it is likely that FLASH will tend to be over-utilized by those with the capability. Collecting for usage, on the other hand, would cause increased use of FLASH to lead to increased costs.

How much extra to charge for a FLASH message is an arbitrary decision. The surcharge could be either a fixed amount or a multiple of the non-FLASH message charge. One decision rule might be to set the FLASH factor so that the projected bill of the largest FLASH user was 10 percent greater than it would be if the FLASH charge were zero. Alternatively, one could make adjustments over time and raise the FLASH factor until the number of FLASH messages fell by, say, 50 percent, or the ratio of FLASH to total is only X percent where X is less than the current number. In time of war, FLASH charges could be eliminated.

The recommendation to charge for FLASH may appear to run counter to our argument that, since total costs are fixed and marginal costs are zero, the direct user should not be confronted with marginal cost decisions and that billing should be

done on an aggregate basis. In selecting a higher precedence, however, the FLASH user, even though he does not increase the total costs of the system, does impose costs on other people (through delaying their messages) and he should pay for this.[1] The non-FLASH users are compensated by paying lower bills. One way in which the precedence costs might be made evident to the user would be to break down the bill into two parts. One part would be the basic charge for ordinary use, with a lump sum figure and no identification of usage by installation or sending office. The other part would be the charge for FLASH messages with a very fine breakdown of the installations and senders generating the FLASH traffic. In this way, and if so desired, pressure could be brought to bear upon those generating the FLASH traffic to minimize its use. Even if such a billing breakdown is not undertaken, the knowledge that FLASH is costly may have some psychological effect in deterring its use.

4. Measurement of Usage

There are two units that can be utilized to measure usage, messages and line blocks. It is possible to set up a system that charges for either or for both. If rates were to be based exclusively on the number of messages, long messages and short messages would cost the same. Given the prevalent and growing use of computers in the system, and the fact that a large data transmission may constitute a single message, the line block seems the appropriate unit upon which to base allocation of costs.

On the other hand, all messages, regardless of length, require a certain amount of header information, record keeping, and billing costs, and involve a fixed amount of synaptic activity within the system. These fixed cost characteristics would

[1] It should be emphasized here that he does not increase the total costs of the system; he simply forces others to wait and thus imposes costs on them.

not be taken into account if costs were allocated solely on the basis of line blocks. In addition, from an equity point of view, in most cases there is probably some fixed value to being able to send a message that is not measured solely by its length.

As a result, it seems appropriate that usage charges be a combination of a cost per message plus a cost per line block. How the two should be set is arbitrary, but the fixed charge per message within the US should probably be less than the first class postage rate of 15¢ since letters are an obvious alternative to AUTODIN. By the same token, the international message rate should be less than the international airmail rate of 31¢. In our simulations, we shall provide examples of how the allocations of cost among users is affected by the choice of various combinations of cost per message and cost per line block.

5. International and Domestic Systems

Although there are real resource costs involved in operating all of AUTODIN, the only costs that we are concerned about allocating are those that are paid through DCA either to commercial firms or civilian government employees. The costs of owned switches outside the U.S. and the wages of military personnel who work in the AUTODIN system are of no concern here. The costs to be shared are accounting costs, not economic costs.

All users of the system benefit from it and there is no justification for attempting to segregate users according to whether they are linked primarily to a wholly-owned switch in Europe or a leased one in the U.S. As a result, all users are to be treated alike, both with respect to connectivity fees and usage fees. The costs are almost exclusively CONUS costs, but everyone shares them.

E. A GENERALIZED MODEL FOR ALLOCATING COSTS

Having examined the significant characteristics of AUTODIN that impinge upon the problem of allocating costs, it is possible now to integrate them and arrive at a general model that can be used to calculate appropriate connectivity, usage, area, and precedence charges as a function of various decision parameters and variables. All of the variables and parameters have been discussed earlier so we simply shall define them and describe how they can be put together to create a model for allocating costs.

We define the following symbols:

S = total annual cost of switches (including both memory and throughput but not trunk leases)

$R = \alpha S$ = total annual cost of memory[1] (total connectivity costs)

D = portion of switch (connectivity) costs to be allocated by connectivity charges

d = connectivity fee per weighted unit

a = ratio of memory used for CONUS trunks to total CONUS memory available (this is 0.23 in the previous example)[2]

b = ratio of memory used for overseas connecting trunks to total CONUS memory available

aR = cost of memory for CONUS long distance

bR = cost of memory for overseas long distance

T_c = cost of CONUS trunks plus area trunks overseas

T_{OS} = cost of overseas connecting trunks

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[1]R can be measured directly or it can be defined as the product of a ratio α and the cost of switches: $R = \alpha S$. This definition is useful if α is either constant over time or is the decision parameter whose value is changed from period to period.

[2]Some thought should be given to whether the denominator of this ratio should be total CONUS capacity or total memory used for all connections. The latter allocates the cost of "unused" memory capacity to both local and long distance.

N = number of weighted units (obtained by multiplying number of low-speed lines by 3, medium speeds by 9, high speeds by 14, and adding)

x = number of local or single switch messages

y = number of area (e.g., CONUS) long distance messages

z = number of inter-area messages.

In accordance with the earlier discussion, aR, bR, T_c and T_{os} (trunks and trunk connections) should be allocated among long distance users as a function of usage. This means that aR and bR should be subtracted from the total connectivity cost before connectivity charges are calculated. Costs to be allocated by *connectivity charges* (symbolized by D) thus would be:

(1) $$D = R - (a + b)R = (1 - a - b)R.$$

The connectivity fee per *weighted unit* would be:

(2) $$d = \frac{D}{N} = \frac{(1 - a - b)R}{N}.$$

This cost should be multiplied by 3, 9, and 14 to obtain the access charges for slow, medium, and high speed, respectively.

The message unit charges must be calculated separately for local, area, and inter-area calls.[1] The cost per message unit for local (single switch) calls, C_1, will include none of the costs associated with long distance. It is equal to switch costs less memory costs divided by the total number of message units:[2]

(3) $$C_1 = \frac{S - R}{x + y + z}.$$

[1]The term "message unit" here refers to either messages or line blocks, whichever is selected as the unit of measure. We later describe the process of calculating charges when both messages and line blocks are assessed.

[2]The switch costs must be allocated among *all* calls, local, area, and inter-area, since all calls pass through the switches.

The total revenue collected for single switch calls would be xC_1.

The cost per message unit for area (CONUS, Europe, or Asia) messages would be that for single switch plus the allocation of costs associated with trunks and trunk connectivity within all areas:[1]

(4) $$C_2 = \frac{S - R}{x + y + z} + \frac{aR + T_c}{y + z} .$$

The area trunk costs are allocated to both area and overseas messages because any overseas message originating at a switch other than the gateway switch will use area trunks and memory capacity as well as the overseas trunks and capacity. The total revenue collected for area messages would be yC_2.

The cost per message unit for inter-area messages would be that for an area message plus the allocation of costs for overseas trunks and connectivity:

(5) $$C_3 = \frac{S - R}{x + y + z} + \frac{aR + T_c}{y + z} + \frac{bR + T_{os}}{z} .$$

The total revenue collected for overseas calls would be zC_3. If one were to add the total connectivity charges and the sum of the usage charges one would find that our formulas produce the correct amount of revenue. This can be shown rather easily.

Connectivity revenue is: $D = (1 - a - b)R$,

Single switch revenue is: $xC_1 = \frac{x(S - R)}{x + y + z}$,

Area revenue is: $yC_2 = y\left[\frac{S - R}{x + y + z} + \frac{aR + T_c}{y + z}\right]$,

[1]The area trunk and area connectivity costs are allocated among both the area and inter-area calls because both sets of calls pass over these trunks. Local calls do not.

Overseas revenue is: $zC_3 = z\left[\frac{S - R}{x + y + z} + \frac{aR + T_c}{x + y} + \frac{bR + T_{os}}{z}\right]$,

Total Revenue is $(1 - a - b)R + xC_1 + yC_2 + zC_3$

$$= (1 - a - b)R + S - R + aR + T_c + bR + T_{os}$$

$$= (1 - a - b)R + S - R + aR + bR + T_c + T_{os}$$

$$= S + T_c + T_{os} .$$

The latter is equal to total costs.

The breakdown for costs and their allocation can be illustrated schematically as shown in Figure 3. The large block which is the total area of blocks 1, 2, and 3 is the total annual cost of switches. It corresponds to S in our algebraic model. The annual cost of memory is the left hand segment of the large box and is labeled ADU memory. It corresponds to R in the algebraic model. That portion of the memory that is absorbed by backbone trunks lies below the dotted line and is identified by the number 3. It is the equivalent of aR + bR in our algebraic model. The backbone trunk lease costs are shown as the small block 4 connected to the memory. In the algebraic model these would be T_c and T_{os}. The subscriber access lines are also shown but the costs of these are paid by users and do not enter DCA's budget.

The area (1-a-b)R is allocated to subscribers in the form of access charges. The area S - R is allocated to all users of the system as a function of usage measured either as line-blocks or messages. That portion of the memory capacity, qR, which is absorbed by CONUS trunks plus the cost of CONUS trunks, T_c, is paid for as a function of usage by senders of area messages. That portion of memory capacity, bR, which is absorbed by overseas trunks plus the cost of overseas trunks, T_{os}, is paid for as a function of usage by overseas message senders.

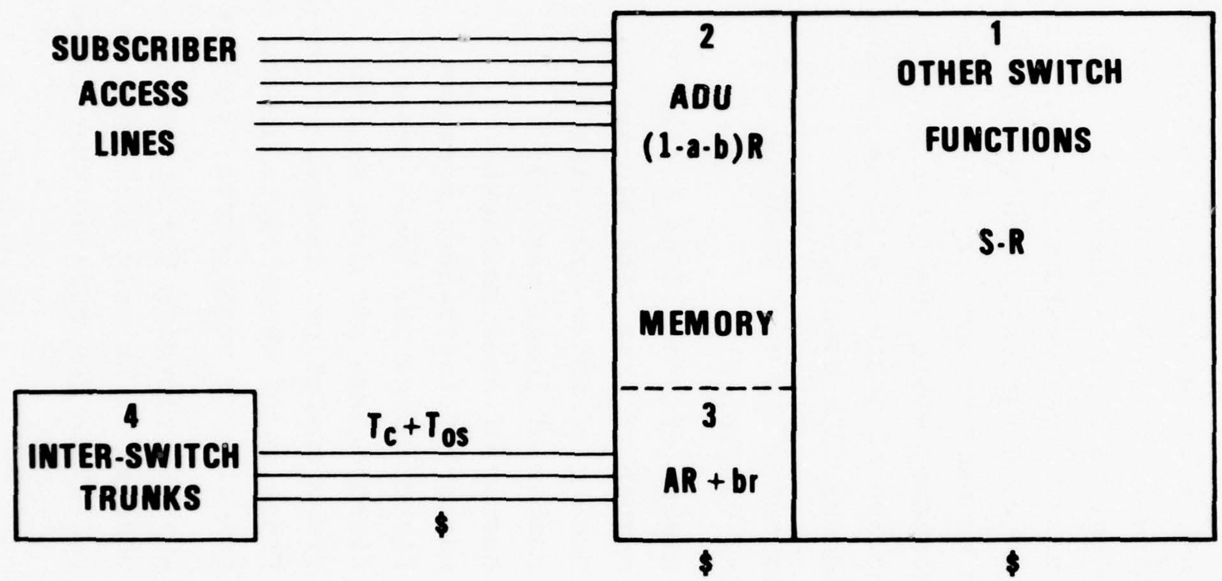

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Figure 3. NOTIONAL ALLOCATION OF COSTS

1. Usage Charges for Both Messages and Line Blocks

The methodology described above is applicable regardless of whether messages or line blocks are the measure of usage. The variables, x, y, and z could be defined as the number of units of either. It is a relatively simple matter to extend the methodology to permit charges to be levied for both messages and line blocks. The breakdown between them can be determined in either of two essentially equivalent ways. One permits a decision to be made on the cost per message, for example 10 cents per local message, while the other permits a decision to be made on what fraction of costs are to be allocated by messages and what fraction by line blocks.

To illustrate how each would be applied, we shall define the following variables:

x = number of local line blocks
y = number of area line blocks
z = number of inter-area line blocks
x' = number of local messages
y' = number of area messages
z' = number of inter-area messages
m_x = fixed charge per local message
m_y = fixed charge per area message
m_z = fixed charge per inter-area message
β = fraction of usage costs allocated to messages
$1-\beta$ = fraction of usage costs allocated to line blocks.

If we wish to exercise the option of assigning a fixed charge per message it is only necessary to select a value for m and then calculate the revenue that these charges bring in:

$$M_1 = m_x x' \tag{6}$$

$$M_2 = m_y y' \tag{7}$$

$$M_3 = m_z z'. \tag{8}$$

The revenue from the messages must be subtracted from the usage cost and the remainder allocated by line blocks.

(3-a) $$\tilde{C}_1 = \frac{S - R - M_1 - M_2 - M_3}{x + y + z}$$

(4-a) $$\tilde{C}_2 = \frac{S - R - M_1 - M_2 - M_3}{x + y + z} + \frac{aR + T_c}{y + z}$$

(5-a) $$\tilde{C}_3 = \frac{S - R - M_1 - M_2 - M_3}{x + y + z} + \frac{aR + T_c}{y + z} + \frac{bR + T_{os}}{z} .$$

If we wish to exercise the option of allocating a certain fraction of usage costs to messages and the remainder to line blocks, the procedure is even more simple. The per unit costs of messages would be:

(3-b) $$\hat{C}_1 = \frac{\beta(S - R)}{x' + y' + z'}$$

(4-b) $$\hat{C}_2 = \frac{\beta(S - R)}{x' + y' + z'} + \frac{\beta(aR + T_c)}{y' + z'}$$

(5-b) $$\hat{C}_3 = \frac{\beta(S - R)}{x' + y' + z'} + \frac{\beta(aR + T_c)}{y' + z'} + \frac{\beta(bR + T_{os})}{z'}$$

The per unit line block costs for local, area, and inter-area would be:

(3-c) $$\bar{C}_1 = \frac{(1 - \beta)(S - R)}{x + y + z}$$

(4-c) $$\bar{C}_2 = \frac{(1 - \beta)(S - R)}{x + y + z} + \frac{(1 - \beta)(aR + T_c)}{y + z}$$

(5-c) $$\bar{C}_3 = \frac{(1 - \beta)(S - R)}{x + y + z} + \frac{(1 - \beta)(aR + T_c)}{y + z} + \frac{(1 - \beta)(bR + T_{os})}{z}$$

2. Precedence Charges

It is a simple matter to introduce differential charges for precedence into the formulas. One only need normalize on

the cost of non-FLASH messages and then multiply this cost by a factor or add some fixed amount to arrive at the FLASH message cost. Equations (2), (3), and (4) would need to be modified slightly to obtain the unit cost for non-FLASH messages. If a factor is used, the modification would consist of multiplying the number of FLASH messages contained in x, y, and z by the factor before summing. The denominators in these equations then would be the number of normalized messages. Alternatively, if a fixed charge per FLASH message is assigned, the total FLASH charge can be subtracted from the costs (S - R) before allocating the remainder. Our program permits any of these methods to be used and also permits local, area, and inter-area FLASH messages to be assessed differently.

We would recommend, however, that precedence *not* be made a part of the process of calculating before-the-fact charges for usage. We believe there should be a charge for precedence but the revenue collected simply should be subtracted from the following year's costs before they are allocated. Agencies cannot reasonably forecast FLASH usage, but a charge and an accounting for such use are desirable from a managerial viewpoint.

F. AUTODIN II

AUTODIN I is a computer-based, store-and-forward message processing system offering three separate services. First, the switches provide a host for users to access the system. Second, each switch is a message processing center offering users convenient facilities for message transmission. Third, the system contains a network of trunk lines for long-haul transmission. The system was designed to provide the necessary communications capabilities for crisis situations. Consequently, it is oriented to narrative traffic, and narrative messages comprise the vast majority of messages transmitted.

However, a growing share of traffic volume is computer-to-computer transmission.

AUTODIN II is a system designed expressly for computer-to-computer linkages including interactive or real-time networks. There are many differences between AUTODIN I and AUTODIN II, but the most significant is that AUTODIN II is designed only to provide linkage. It will be a datagram service offering users an electronic pipeline with which to transmit messages to other users. All other facilities must be provided by the user. As contrasted to circuit-switching or message-switching, AUTODIN II will be packet-switching.

A packet is simply data encoded in digital form preceded by a header signifying, in the case of AUTODIN II, both the recipient and the sender. In a packet-switching network, all transmission is packets. Any message must be decomposed into packets for transmission, and the recipient must reassemble the packet into the original message. The system transmits only one packet at a time. In AUTODIN I, by contrast, the system accepts and is responsible for an entire message.

The AUTODIN II system will consist of a number of switching centers, each containing one or more computers, and high speed (50,000 baud) transmission lines linking these computers. To facilitate access to the system, channel control units will be provided to interface between AUTODIN II users and AUTODIN II switches, and these units will perform the necessary message-to-packet and packet-to-message transformation. In a circuit switching network, the path between two users may vary from connection to connection, but once established the path remains fixed. In a packet-switching network such as AUTODIN II, the path between any two users may vary from packet to packet, providing both maximum efficiency in utilization of the system and greater security. Connection is established between users and the system rather than from one user to another.

Once connected, a user may enter packets into and receive packets from the electronic pipeline the system provides. All users will have a coded logical address. For maximum security, the system will insert the address of the sender into each packet transmitted and will restrict each user to transmission only to authorized destinations. The system recognizes only packets, so that sequential packets may have different recipients. If a recipient is not currently connected, the system transmits to the sender an error message.

Since AUTODIN II is still in its formative stage, some of what follows must be speculative. Both AUTODIN I and AUTODIN II will be operating simultaneously for some time, since they provide different services and perform different functions. However, AUTODIN II will replace the trunks which now connect the AUTODIN I switches, so that AUTODIN I will be a major user of AUTODIN II. This creates a number of possibilities for overlap, as access to either system will provide access to both. The AUTODIN I switches will become service centers providing specific message processing capabilities. In addition, the AUTODIN I switches will be the host for low speed users who otherwise could not connect to the communications network.

Most of the same characteristics that determine cost allocation in AUTODIN I exist in AUTODIN II as well. A connectivity fee is called for since increasing the number of users connected to a given AUTODIN II switch will increase the number of computers required to service that switch and the number of channel control units required to provide the necessary interface. From a cost point of view, these computers play a role analogous to that of the ADU's in AUTODIN I.

Utilization charges would require somewhat different treatment in AUTODIN II from what we have suggested for AUTODIN I. The number of packets transmitted provides a reliable measure of usage but unless some changes are made in the proposed

software governing data accumulation, there will be no possibility of charging for distance. The software currently under consideration keeps track only of the total number of packets transmitted by a user and does not record destination. It will still be possible to bill AUTODIN I users for distance, however, even though their messages are transmitted on AUTODIN II trunks, since the same information that is currently collected will still exist at the originating AUTODIN I switch.

It is technically feasible to install software that would permit billing for distance on AUTODIN II but only at a cost. We have no information at present on what this cost would be and as a result cannot assess whether the additional software would be worth acquiring. Much depends on the amount of AUTODIN I traffic that remains and on the distribution by distance of the AUTODIN II traffic.

It is quite possible that not charging for distance could produce some perverse incentives in the choice and use of communication facilities. For example, many users in the same area will be connected to the same AUTODIN II switch. If the traffic between them is fairly large, they may find that a direct connection costs them less than paying for transmission via AUTODIN II when all message units are billed at the same price. Lower charges for local AUTODIN transmission would mitigate against such practices. There may also be another incentive problem. Store-and-forward message processing requires two elements: a processing computer and a linking network. Since AUTODIN II will provide the linking network, agencies might find it efficient to create their own message processing system using their own computer. While this may be cost effective from the viewpoint of the U.S. Government as well as from the viewpoint of the agency, it does risk losing a valuable commonality in protocol. A lower charge for local transmission would keep a central system such as AUTODIN I

more cost competitive. In this report, we can only recommend that these potential problem areas be investigated and appropriate policy established.

Even though it may not be possible to charge for distance there should certainly be a charge for the use of precedence. With AUTODIN II, precedence is potentially more disruptive than it is in AUTODIN I. Use of a high priority in AUTODIN I only delays receipt of lower priority messages; in AUTODIN II, precedence use may cause communications between users to be broken. For short messages, the cost may not be great, but with long transmissions the cost of reconstituting a message and beginning again may be considerable. Abuse of precedence is a potentially serious problem if there are no costs imposed on FLASH users. If some subscribers find their own communications activities are being hindered because of other's use of FLASH, they will respond by using FLASH themselves if they have the capability, thus increasing the number of preemptions suffered by non-FLASH users. The actual harm from excess use of precedence may be slight given the design and implementation of the system, but proper pricing rules that impose costs on the use of precedence might prevent a problem from ever developing. It is presently planned that the right to precedence would be charged for as part of the access fee. It appears more sensible to charge for precedence use by packets transmitted than by access, however.

There is one final complication in AUTODIN II--the possibility of having dial-in and dial-out customers. These users would not have their own access lines but would connect for a limited time via telephone lines or similar access. A sensible basis for charging these customers would be connect time, the elapsed time the user actually is connected to the AUTODIN II system. Charging for connect time is a standard feature of commercial algorithms for similar computer or communications networks, however, and should present no problems.

In conclusion, to the extent possible, a single pricing schedule should be developed for the integrated AUTODIN I and AUTODIN II system. As we have noted, there are some differences in careful analysis. The major objective should be to design a pricing structure that contains the least amount of perverse incentives to users and encourages efficient use of existing communications capabilities while staying within the constraints imposed by cost and technology. This is an area that will require continuing study as AUTODIN II develops in order that the information needed for the billing system can be one of the elements taken into consideration in selecting software for AUTODIN II.

III. SENSITIVITY TESTING OF THE AUTODIN RATE MODEL

The cost allocation model developed in Chapter II implies certain relationships among costs, network characteristics, and system use that yield varying rates to recover backbone costs. In order to investigate these relationships as a step toward predicting the impact of such a cost allocation system as is proposed, a computer simulation expressing the model was developed and applied to a DCA collected sample of actual AUTODIN traffic.[1] An estimate of system costs for FY 1978 from budget submissions was used to provide the financial input. The simulation produced as output the monthly charges and message rates implied by the input parameters, as well as the resulting distribution of backbone costs by agency.[2]

A. PARAMETERS AND THEIR VALUES

The model, as described in Chapter II, makes the rates to be charged for connectivity (access) and usage dependent upon: the division of total costs between switching services and trunks, the fraction of switch cost which is ascribable to ADU memory (α), the number and speed of access lines, and the number of trunk terminations of switches as divided between intra- and inter-area trunks. Some of these inputs are projected or actual costs which the model uses to compute parameters such as α; others are decision variables, such as message surcharges

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[1] The IDADIN computer simulation and the DCA data are documented in Appendixes B and C. The data sample was for seven days of system traffic. However, the simulation has expanded this to an annual basis.

[2] Facsimiles of the output formats are included in Appendix B, Vol. II.

which DCA might want to use to achieve its various objectives. Other values are derived from technical relationships such as the network arrangement of switches, trunks and subscriber lines.

The model provides the option of calculating either the line block rates or the message charges or any combination of both that will recover all costs. If the user wishes to fix the surcharge for messages in each distance category and then calculate the line block rates needed to recover remaining usage cost, he may specify such an option. The model also permits the user to impose a weighting factor for distance that will apply to calculating line block or message rates. Finally, a weight or surcharge can be specified for all FLASH messages, and the effect on other rates assessed.

For the sensitivity tests discussed below, certain inputs were fixed. The costs are approximately those in the FY 78 budget. Annual switch costs were set at about $44 million. From various sources it was estimated that from 18-22 percent of switch costs could be attributed to ADU memory; so α was set at 20 percent yielding about $8.8 million as the memory cost. Leased trunks in the U.S. were estimated at about $356,000 per year and overseas trunks (inter-area) at $1.8 million. The exact figures and additional definitional material are given in Table 4.

On the technical side, certain characteristics were assumed to be fixed, although as a practical matter small changes are constantly occurring in the actual network configuration. All nine leased switches were included in the calculations and assumed to have 2,340 line blocks of ADU memory each (eight quadrants). The number of trunk terminations in CONUS was set at 56; from overseas at 17. Each was assumed to use 28 line blocks of assignable ADU memory at the switch.

Table 4. IDADIN COMPUTER SIMULATION INPUTS AND OUTPUTS

A. INPUTS

Description Name	Program Name	Model Symbol	Value	Comments
Switch Cost	SWCOST	S	$43,944,160 (Computer Input is 1/52 of above value)	This is the approximate lease and O&M cost for all switching centers in FY 78
ADU Memory Cost	MCOST	R	9,000,004 (Computer Input is 1/52 of above value)	An estimate of ADU lease costs, nine leased switches assuming two ADU per switch
CONUS Trunks	TRIC	T_c	355,992 (Computer Input is 1/52 of above value)	Defined as cost of all area trunks, i.e., trunks connecting switches in same charging area (CONUS, Europe, etc.). Value here is for CONUS trunks only.
Overseas Trunks	TROC	T_{os}	1,781,988 (Computer Input is 1/52 of above value)	Defined as cost of trunks connecting switches in different areas. Value used here is for all overseas leased trunks.
Area Memory Capacity	LBLKS	See a and b below	21,060	Line blocks of ADU memory in all leased switches assuming eight quadrants of memory per ADU, 18 ADU's (Hawaii switch is included with CONUS).
Area Trunk Terminations	TRKC	See a and b below	56	Count of leased switch interconnections.
Inter-area Terminations	TRKI	See a and b below	17	Number of trunk terminations at leased switches from overseas.
(Ratio of ADU memory used for area trunks to total)	n.a.	a	(0.0745)	(The three inputs above assuming 28 line blocks of ADU memory used per trunk termination are used to calculate a and b inside the simulation.)
(Ratio of ADU memory used for inter-area trunks)	n.a.	b	(0.0226)	

(continued on next page)

Table 4 (continued)

Description Name	Program Name	Model Symbol	Value	Comments
Sample Usage Data	n.a.	x, y, z, N x', y', z'	See printout.	The simulation used a 7-day sample of AUTODIN I traffic, the characteristics of which are displayed in the output. Counts of the number of connections by speed, number of line-blocks and messages transmitted by precedence and distance were read from DCA-supplied tapes and converted to an annual basis to produce the results shown in the output.
B. USAGE PARAMETERS				
Cost Factors	BLOCKS	β $1 - \beta$	Values may range between 0 and 1. (1.0 in representative case)	A 0.0 value for BLOCKS is equivalent to assigning all usage charges on a message basis, a 1.0 value assigns all message charges on a line-block basis. Calculated after all surcharges have been deducted.
	MSGWTS		May take on any value. (Values of 1.1.1 in representative case)	A set of weighting factors for local, area, and inter-area non-flash messages.
	FLASH		May take on any value. (0.0 in this case)	Single weight applied to all FLASH messages.
	MSGCHG		May take on any value. (10¢, 15¢, and 30¢, respectively. 0.0 for FLASH in case shown)	These surcharges are applied on a per-message basis and subtracted from costs to be collected through usage before calculation line-block and message rates.

(continued on next page)

Table 4 (concluded)

Description Name	Program Name	Model Symbol	Value	Comments
C. OUTPUTS - RATE ANALYSIS				
Cost Allocation				
Utilization	n.a.	xC_1, yC_2, zC_3	\$37.956 millions	These two values are produced by the model, given switch and trunk costs, ADU memory costs and the fractions of ADU used by trunks and terminals.
Connectivity	n.a.	D	8.126 millions	
Access Charges				
Base Charge	n.a.	d	95.25	This is the monthly basic charge for connectivity which multiplied by 3, 9, and 14 (for slow, medium, high) for connectivity yields the value D over all connections in the sample.
Utilization Rates				
Line Blocks	n.a.	$\tilde{C}_1, \tilde{C}_2, \tilde{C}_3$	\$0.0034, \$0.0038, \$0.0047	Line block charges after message surcharges (M_1, M_2, M_3) are deducted from utilization charges.
Messages	n.a.	m_1, m_2, m_3	\$0.10, \$0.15, \$0.30	As inputs in this case, but would be calculated if Blocks < 1.0.
D. OUTPUTS - BACKBONE CHARGES				
Agency Charges and Breakdowns	n.a.	n.a.	As shown	These results show the annual dollar equivalents for the "agencies" (= sum of same first letter PDC codes) and their percent breakdown. Valid for inputs as shown.

B. TRAFFIC SAMPLE

The distribution of message traffic by distance, speed class, and precedence among various originating agencies for the simulated one-year period was assumed to be the same as in the sample of 1976 AUTODIN traffic supplied by DCA. The sample contained 1,322 access lines of which 893 were slow, 315 were medium, and 114 were high speed. These were assigned to "agencies," which are the budgetary entities controlling communications access.[1] Approximately 51 percent of the messages and 46 percent of the line blocks were accounted for by two agencies. The five largest users accounted for over 80% of the messages and 92% of the line blocks. The division of messages among local, area, and inter-area was 29%, 25%, and 46%, while line blocks were allocated in the ratios of 26%, 21%, and 53%. FLASH precedence traffic was 1/2 of 1% of messages and 1/10 of 1% of line blocks indicating that FLASH messages are considerably shorter than average.[2]

C. SIMULATION AND SENSITIVITY ANALYSIS

The model we have developed provides a rich variety of possibilities in terms of alternative ways of allocating costs. First, it is possible to vary the allocation between usage and connectivity. Second, the usage itself can be allocated either as a function of messages, or line blocks, or both. Third, charges can vary as a function of distance. Fourth, fixed

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[1] The data tapes provided a four-character alpha-numeric PDC code to identify each constellation of lines. The "agencies" represent the aggregation of all PDC codes with identical initial characters. Appendixes B and C provide those who have access to the codes with information to identify offices and agencies. The study group preferred to do their analysis without considering agency identities so as not to prejudge from other knowledge.

[2] Many of these may be test messages designed to regularly exercise command and control links for contingencies.

surcharges can be levied for various classes of messages, by distance or precedence. In order to display most clearly the effects of changing the cost allocation procedures, we have prepared a series of tables which relate the values of various outputs, connectivity fees, message unit charges, and the distribution of costs among users to the values of various input parameters. The backbone costs used are the projected costs for FY 78. The traffic figures are a one-week sample collected by DCA in 1976. A complete description of the sample is contained in Appendix B.

Table 5 contains the results of several different simulation exercises. The upper part of the table shows the percentage of total costs borne by each of the agencies under different methods of allocating costs; the next block of figures indicates the monthly connectivity fees that would be assessed; the final two blocks contain the per-unit charges that would be levied on line blocks and on messages.

To provide a benchmark for comparison, Table 5, Column A, shows the connectivity fees and sharing of cost among agencies that will exist if the current system of allocating costs solely as a function of connectivity is continued, and if the future traffic is distributed in the same way as the study sample. Agencies are identified only by a letter in order that results not be prejudged in terms of whom they affect.[1]

Column B of Table 5 shows the results that are obtained using a much different set of parameters. The switch leasing costs are allocated in the ratio of 20 percent to connectivity and 80 percent to utilization. Utilization is charged as a function of line blocks, while distance charges are assessed in accordance with the method discussed on pages 30 and 31

[1]"Agency" as used here is a construct provided by summing on the first character of a four-digit alpha-numeric "program designator code" obtained from DCA-supplied computer tape records.

Table 5. COMPARATIVE SIMULATION RESULTS

Agency	A 100 Percent Connectivity	B α = 0.20 Line Blocks	C α = 0.20 Messages	D Representative Case, Message Surcharges
		Percent of Total Backbone Cost		
A	30.46	27.69	24.81	26.84
B	16.86	14.05	11.43	12.85
C	20.58	19.60	26.36	23.27
D	7.09	4.03	6.72	4.70
E	1.17	1.20	1.11	1.10
F	1.56	0.32	0.41	0.36
G	5.20	18.00	13.55	16.34
M	0.13	0.03	0.04	0.03
N	0.13	0.02	0.03	0.02
P	2.78	1.19	1.33	1.19
W	0.17	0.05	0.06	0.05
X	1.27	1.49	1.30	1.36
6	12.60	12.32	12.85	11.89
(Totals may not add to 100 due to rounding)				
Monthly Connectivity Charge				
Base	541.41	93.01	93.01	93.01
Low Speed	1,624.22	279.04	279.04	279.04
Medium Speed	4,872.65	837.11	837.11	837.11
High Speed	7,579.68	1,302.17	1,302.17	1,302.17
Use Charges				
Line Blocks:				
Local	n.a.	0.0086	n.a.	0.0035
Area	n.a.	0.0090	n.a.	0.0038
Inter-Area	n.a.	0.0099	n.a.	0.0047
Average Message Cost:				
Local	n.a.	0.3159[1]	0.3442	0.2286[2]
Area	n.a.	0.2968[1]	0.3581	0.2753[2]
Inter-Area	n.a.	0.4501[1]	0.4000	0.5137[2]

[1]The average line block length for these messages is 36.73 for local, 32.98 for area, and 45.96 for inter-area.

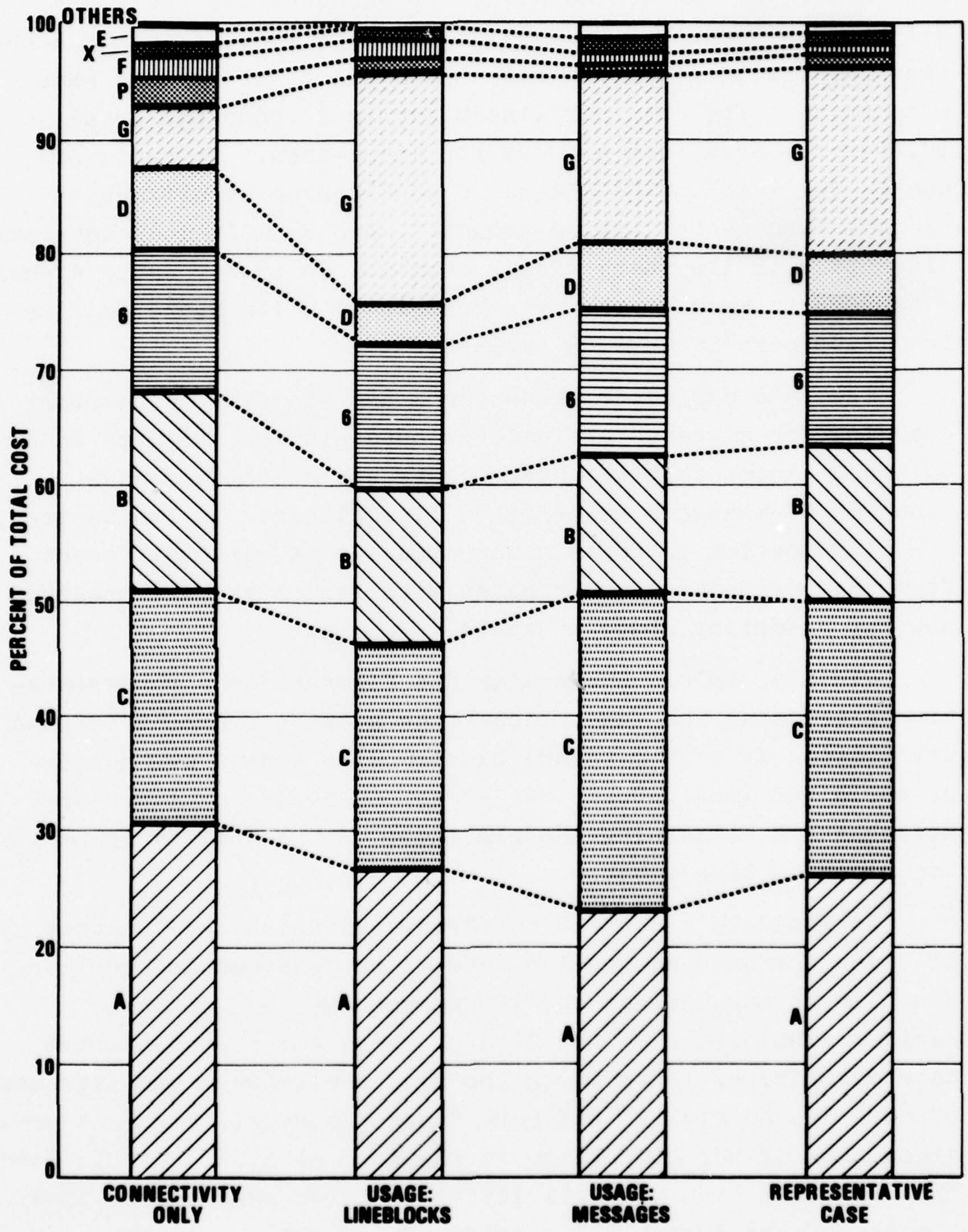
[2]The average line block length is the same as Case B. The surcharges are $0.10 for local messages, $0.15 for area, and $0.30 for inter-area messages.

in Chapter II. As can be seen, the connectivity fee for a weighted unit falls from \$541.41/month of \$93.01/month and the fees for low, medium, and high speed lines fall by the same proportion. The cost per line block is \$0.0086 for local, \$0.0090 for area, and \$0.0099 for inter-area. There is no charge for FLASH. The shares of costs borne by different agencies change by varying amounts. Agency G is most adversely affected with its share rising from 5.2 to 18 percent. Agency F appears to receive the most benefit with its share falling from 7.09 percent to 4.03 percent.

The same parameter value for α and the same method for charging for distance are used in obtaining the figures in Column C except that all usage costs are calculated as a function of messages rather than line blocks. As can be seen, the distribution of costs among agencies is quite different from that of Column B. Agencies with longer average messages now pay a smaller share of costs.

Finally, Column D contains the figures for a representative case using the same allocations between connectivity and utilization (α = 20 percent) but imposing a cost per message of \$0.10 for local, \$0.15 for area, and \$0.30 for inter-area messages and allocating the remainder of the utilization costs according to line blocks.

As would be expected, the "representative case" shares of costs for each agency lie between the extremes of 100 percent line block charges and 100 percent message charges. Further examination of the figures shows the representative case distributes costs among the agencies between the extremes of pure "connectivity" and pure "usage" models. Figure 4 provides this agency comparison in the form of a bar chart. Note that shifting from connectivity to usage as measured by line blocks affects Agency "G" significantly, while shifting to usage as measured by messages has a major impact on Agency "C".



5-5-77-19

Figure 4. EFFECT OF DIFFERENT ALLOCATION PRINCIPLES ON "AGENCY" COST SHARES

The "representative case," were its values adopted in setting rates, would impose upon Agencies C, 6, and G significant budget increases compared to those faced with pure connectivity; Agencies D and B would experience substantial reductions.

Clearly, there are an infinite number of combinations of inputs that could be tried with different results. We cannot present all of them but we can provide some illustrations of what happens to various output values as one input parameter is varied while all the others are held constant at some arbitrary value.[1]

D. EFFECTS OF VARYING α

Figure 5 graphically illustrates how the choice of α, the ratio of memory to total switch costs, affects the allocation of costs between connectivity fees and usage charges. The usage allocation is further broken down to indicate the shares collected from local, area, and inter-area users. Some usage charges remain even when α is one and switch costs are collected entirely through a connectivity fee, because trunk leasing costs are allocated to area and inter-area calls.

In looking at the solid line in Figure 5, we see that as α increases from zero to 100 percent of switch costs, the fraction charged to connectivity rises from zero to 81 percent of the backbone cost. The dotted lines show how the utilization charges would be distributed among local, area, and inter-area communications assuming line blocks are the units of usage charged for. At $\alpha = 0$, local message traffic would pay about 25 percent of all backbone costs, area traffic would pay for about 17 percent, with the remaining 58 percent collected from inter-area traffic.

[1]Appendix C provides a program listing and documentation of the IDADIN Cost Allocation Model as programmed for a CDC 6400 computer. The effects of any combination of inputs, given a sample of AUTODIN traffic in appropriate form, can be readily assessed (CP time for 10 variations is less than 30 seconds) using the program.

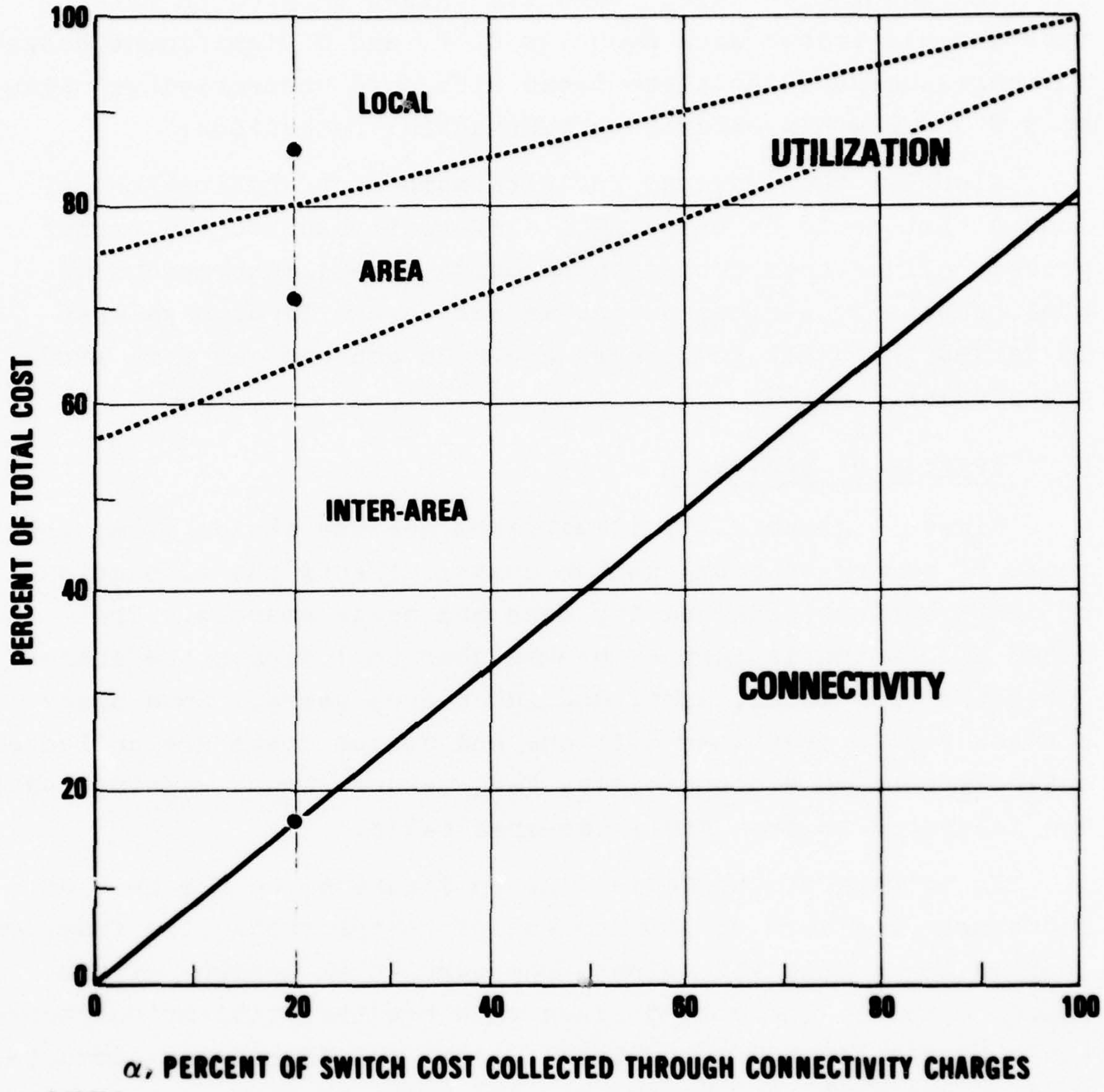


Figure 5. EFFECT OF VARYING α ON THE DISTRIBUTION OF COSTS (Usage Measured by Line Blocks)

The dots in the left-hand portion of Figure 5 mark the allocations for the "representative case." The first dot from the bottom is the dividing point between "connectivity" and "utilization" when α = 20 percent. In this case, connectivity is 17 percent of total cost. The second dot shows that about 53 percent of total cost is paid for as an inter-area use charge. The last dot shows that the remaining 30 percent of cost is equally divided between area and local use charges.

The effect of varying α on the budget of each agency, compared to its costs under the present system, is shown graphically in Figure 6. The impact on Agency "G" is noteworthy, and reflects its large volume of traffic from relatively few terminals.

The effect on agency budgets of different allocations of costs between connectivity and usage, with usage measured alternatively by line blocks and messages, is shown in Table 6. Assuming that users' demand for the services is unaffected by the rate structure, the table gives an idea of resulting AUTODIN billings to recover a $46 million backbone cost. The "pure connectivity" case approximates current backbone cost distribution. One can see that among major users, Agencies A, B, and D would pay considerably less if only 20 percent of switch costs were collected through connectivity fees and the remainder allocated on the basis of usage. Agency "6" would be unaffected and Agency G would find itself paying approximately three times the amount it pays under the current connectivity pricing scheme. Agency G is also the agency most affected by the choice between line blocks and messages of usage. Small volume users such as F, M, N, and W would be relatively much better off under usage pricing, although the absolute dollar amounts are not impressive.

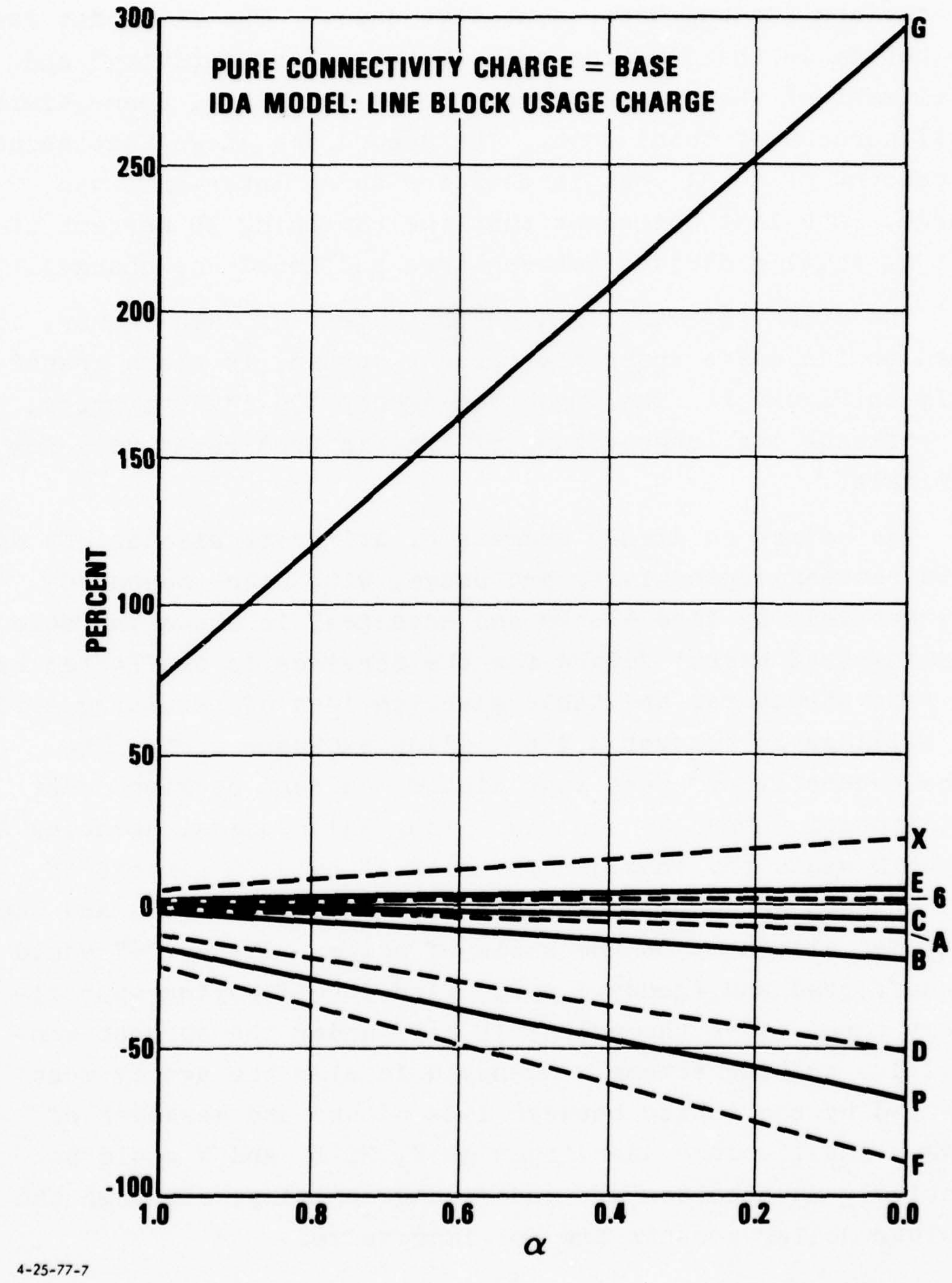


Figure 6. EFFECT OF VARYING α ON "AGENCY" COSTS

Table 6. AGENCY'S BACKBONE COSTS UNDER RATE STRUCTURES

(Thousands of dollars)

Agency	Pure[a] Connectivity	Usage Charge for[b] Line-Blocks Only		Usage Charge for[c] Messages Only	
		$\alpha = 0.8$	$\alpha = 0.2$	$\alpha = 0.8$	$\alpha = 0.2$
A	14,037	13,598	12,762	13,181	11,433
B	7,769	7,310	6,473	6,864	5,268
C	9,484	9,289	9,030	10,494	12,149
D	3,267	2,700	1,859	3,030	3,097
E	539	537	555	521	513
F	719	504	149	518	190
G	2,396	4,716	8,293	3,954	6,244
M	60	41	13	43	17
N	60	40	10	41	12
P	1,281	994	549	1,020	612
W	78	58	23	58	26
X	585	620	686	589	600
6	5,806	5,675	5,677	5,768	5,923

[a]The pure connectivity example is the current billing system. The percentage shares that correspond to these numbers are shown in column A of Table 5.

[b]The percentage shares that correspond to the numbers for $\alpha = 0.2$ are shown in column B of Table 5.

[c]The percentage shares that correspond to the numbers for $\alpha = 0.2$ are shown in column C of Table 5.

E. PRECEDENCE CHARGES

The DCA traffic sample identified FLASH traffic by agency and by local, area, and inter-area categories. Relying on this information, the simulation program was used to examine the effects on agency budgets of applying a surcharge for FLASH messages. We can make no recommendations about the correct surcharge level. There are no significant operating costs that should be allocated to FLASH messages. The costs they impose are paid by others in the form of longer times required to have a message delivered. A surcharge would allocate the delay costs to those who cause them and deter excessive use of FLASH messages.

The rate structure used in examining the effect of different surcharge levels on budgets was that for the representative case (α = 0.20, local message surcharge of 10¢, area surcharge of 15¢, inter-area 30¢).[1] The FLASH surcharge was varied from zero to $30 per message and the budgetary effects calculated for each agency. Figure 7 shows the percentage change in each agency's backbone cost as a function of the surcharge level. Agency D, the most seriously affected, would find its budget increased by approximately 40 percent with a $28 per FLASH message surcharge. Agency G would find its budget reduced by nearly 40 percent.

F. USING THE SIMULATION

The number of possibilities that can be explored is limitless. For example, there are many different rate charge arrangements that result in the same allocation of costs among agencies. As an exercise, the shares of total costs were held nearly constant and alternative rate structures were generated. The value for α was 0.2 and usage charges were assumed to be

[1]See Table 6 for a complete description of the assumed rate structure.

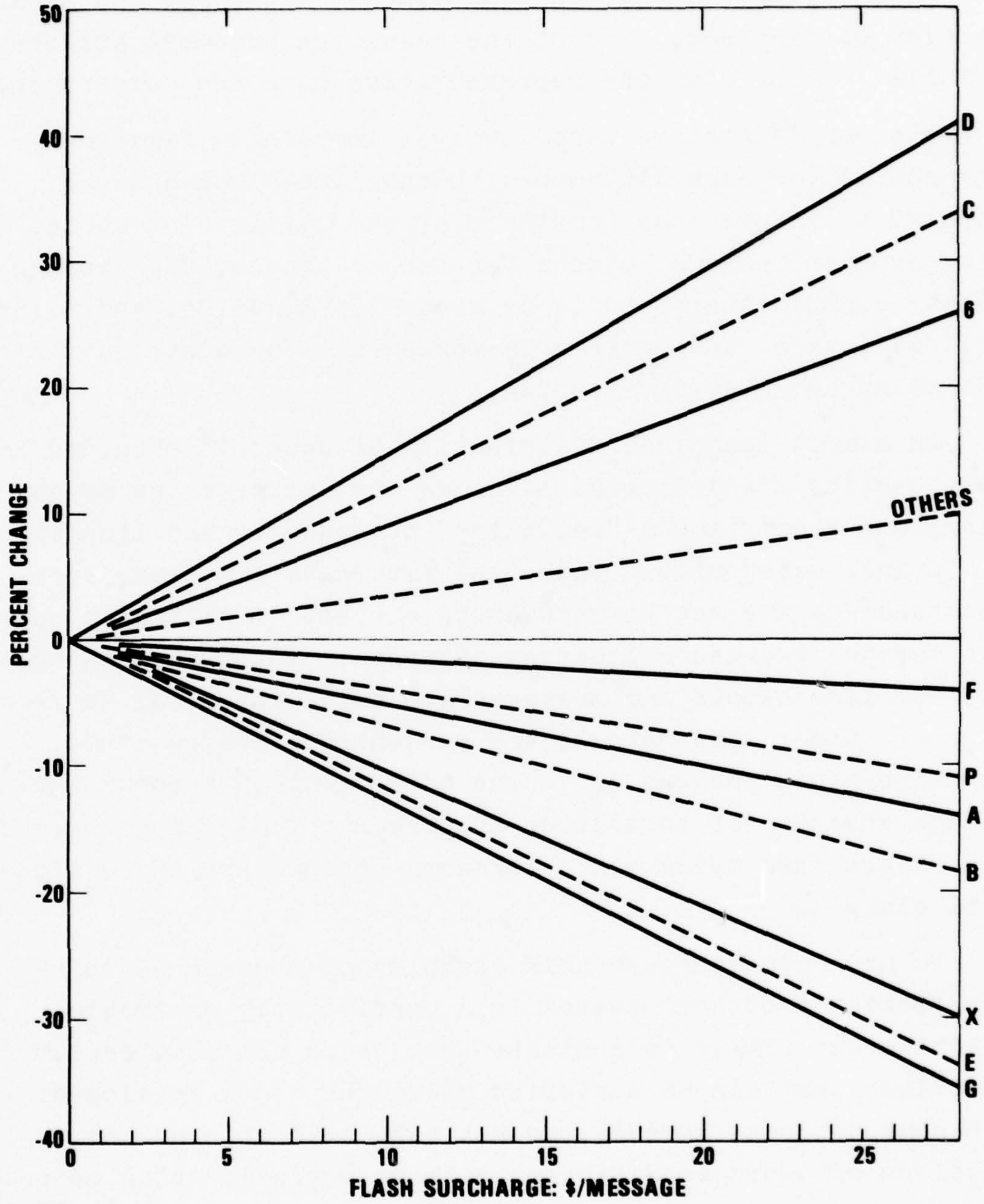


Figure 7. EFFECT ON AGENCY COSTS OF FLASH MESSAGE SURCHARGE (Representative Case)

collected in various ways on line blocks, messages, and as a function of distance. Two of the resulting outcomes are shown in Table 7 along with the representative case for comparison.

The representative case involves imposing a fixed message charge for each distance with the line-block charges computed to recover the remainder of the utilization costs. Using average message lengths for each distance, the average message charges are found to be about \$0.23, \$0.28, and \$0.51 for local, area, and inter-area messages. The distribution of cost among agencies is as shown.

An almost identical distribution of costs is obtained in the Alternate 1 and Alternate 2 cases by dropping the message charge and specifying a "weighting" of messages and line blocks by distance categories. Under the Alternate 1 scheme, line-block charges are set to recover 60 percent of allocated costs with message charges collecting the rest. Inter-area charges both for line blocks and messages are twice the local or area charges. Under Alternate 2, the percentages are reversed, with line-block charges set so as to collect 40 percent and message charges set to collect 60 percent of allocated costs. Area charges are twice and inter-area charges are three times local charges.

We have gone through this example not because we think that stability of cost shares is a particularly desirable objective but simply to indicate that there are a number of objectives that can be satisfied using the model developed. Such computations, however, do not take into account the reactions of users to different methods for allocating costs. Even though we would predict that the elasticity of demand for AUTODIN services, with respect to fees on usage, is rather low, it is nevertheless possible that shifting from pure connectivity to connectivity plus usage will affect demand and that there would also be differences between a situation where

Table 7. ALTERNATIVE CHARGING MODES (α = 0.2 in all cases) (IDADIN Model - 1976 DCA Sample Data)

Parameters	Representative Case[a]	Alternate 1	Alternate 2
Ratio of Usage Charges: Line blocks/Messages[b]	1/10	0.6/0.4	0.4/0.6
Use Weights: Local/Area/Inter-Area[c]	1/1/1	1/1/2	1/2/3
Surcharges ($/Message):			
Local	$0.10	none	none
Area	0.15	none	none
Inter-Area	0.30	none	none
Results			
Average Charge per Message:			
Local	$0.2286	$0.2256	$0.1500
Area	0.2753	0.2287	0.3035
Inter-Area	0.5141	0.5435	0.5504
Agency Shares of Backbone Cost (%)			
A	26.84	26.83	26.79
B	12.85	12.84	12.76
C	23.27	23.40	23.62
D	4.70	4.95	4.54
E	1.10	1.05	1.08
F	0.36	0.37	0.36
G	16.34	16.53	16.32
P	1.19	1.16	1.17
X	1.36	1.29	1.37
6	11.89	11.46	11.88
Others	0.10	0.12	0.11

[a]The parameters for the representative case: α = 0.2; Message charges are $0.10 local, $0.15 area, $0.30 inter-area.

[b]In the representative case this ratio applies to the costs that are not covered by the message charge.

[c]These figures are the ratios of local, area, and inter-area message and line-block charges.

the average cost per local message, for example, was 30¢ rather than 15¢.

We should emphasize that the calculations of costs and their distribution are based on data from a particular one-week sample of usage and do not take into account any charges either in number of connections or in message volume or length that may occur as the result of adopting a different method of cost allocation. Since one of our objectives is to institute an allocation system that would lead to increased utilization of AUTODIN, we believe that the charges calculated from the simulations overstate to some degree those that would actually result. Some trial periods will be required before user behavior stabilizes under a new system for allocating costs. The model is in part a management tool that should be used in combination with observed or projected changes in usage as the cost allocation system is changed. Initially, several iterations may be required before a cost allocation system is settled upon. In the early stages, DCA may find that the problem of projecting usage and of selecting appropriate charge levels is a substantially more complex task than simply varying parameters in the model.

IV. BUDGETS AND BILLING PROCEDURES

Since the real purpose of selecting rates for the services offered by AUTODIN is one of allocating a fixed amount of costs, we think consideration should be given to adopting a billing system which allocates these costs after they have occurred rather than attempting to do so in advance.

DCA is not in the business of selling services to maximize profits. Its function is one of contracting for communications services and acting as a broker between the Defense agencies and the communications suppliers. The Communications Services Industrial Fund's rate-making activities serve primarily an accounting function: to determine in as equitable and efficient a manner as possible how the actual realized costs are to be shared among the users. The processes by which the Fund currently estimates its needs and the agency appropriation requirements have been described in Chapter II. In summary, estimates are made in advance of the total cost of AUTODIN for a year. Estimates also are made of the potential service demanded by various agencies (where service is defined in terms of numbers of access lines). A charge per unit of service then is calculated using projected cost as the numerator and projected demand as the denominator; this is the unit cost used by the agencies in calculating their projected budgets for the fiscal year.

If, as almost invariably happens, the actual demand for service during the year is different from the projected demand (i.e., the number of access lines actually in service is different from projections), the total revenue transferred to the

CSIF from the agency budgets does not match the projections. Income to the fund is typically less than projected, creating a shortfall, unless costs also decline. This shortfall is added to the next year's projected costs and becomes a part of the next year's rate structure.

This system is inefficient because users, making calculations on the basis of these projected average costs, have an incentive to game the system and overstate their projected communications needs (and budgets), knowing that if they underutilize the services, the unspent communications budget will be available for other purposes. Explicit recognition that the CSIF is functioning essentially as an accountant allocating costs, together with shifting to billing for use after it has occurred, would eliminate this source of inefficiency. AUTODIN budgets would need to be restricted solely to AUTODIN.

It may be useful to illustrate with a numerical example what may occur under the present billing system. Suppose total costs for the AUTODIN system for a year are $50,000,000 and the projected total usage is 100,000 units, with agency "A" projecting 4,000 units.[1] The unit cost that is settled upon as a price per unit actually used is then $500. Suppose that over the year the agency uses only 3,500 units but all other users are precisely on target. Agency "A" is left with a surplus in its budget of $250,000 and the CSIF has a deficit of $250,000. This $250,000 is added to the next year's budget and, if all other conditions are the same, the unit charge for the following year, for all users, would be $502.50. The shortfall agency thus ends up with a net gain of $250,000 in its first year budget and could do the same thing in following years.

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[1]We use "units" here for illustrative purposes only without specifying what they are supposed to be.

Conversely, had agency "A" exceeded its projected demand by 500 units, it would have been billed $250,000 more than its budget. The following year the unit charge per unit of service would fall to $497.50. It seems rather obvious that there are incentives not to underestimate the communications budget. There also exists among most users the belief that those who overestimate their budgets are subsidized by those who do not. This belief is fallacious but anyone adhering to it will also tend to overestimate his usage simply to protect himself against what he considers to be the forced subsidization of usage shortfalls by other agencies.[1] Given the uncertainty that may exist about demand for AUTODIN service, there are also legitimate reasons why it could be expected that usage would be overestimated.

Overestimation of budgets and services required has become prevalent and can be illustrated by looking at budgeted and actual numbers of AUTODIN access lines over a six-year period. Table 8 shows the figures from 1972 through 1976 and 19TQ.

Billing agencies at the end of the year for their actual AUTODIN use and for actual costs would ensure that the costs of the service are paid for by those who use them at the time they use them. Since agencies must budget for the future, however, it would not necessarily eliminate the tendency for overestimation of demand. Nor, in fact, is it particularly important to eliminate this tendency if actual costs are billed and each agency's AUTODIN budget is restricted solely to paying AUTODIN charges and cannot be used otherwise. Under these

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[1] If one agency overestimates the number of service units it will require, *all agencies benefit* since the average cost per unit will be lower for all. The following year all agencies must make up the shortfall but what each pays will be approximately equal to the amount by which it benefitted earlier, if demands are relatively unchanged. The agency that overestimates its demand benefits not at the expense of other agencies but at the expense of taxpayers as a whole since it ends up with excess funds that it can spend as it wishes.

Table 8. AUTODIN ACCESS LINES (Year End)

FY	Budgeted	Actual	Percent Difference
1972	1204	1224	1.6
1973	1425	1430	0.3
1974	1340	1374	2.5
1975	1425	1297	-9.0
1976	1389	1168	-15.9
19TQ	1385	1180	-14.8

circumstances, if an agency had a surplus (or a shortfall), it would be required to apply it against the coming year's AUTODIN budget (or in the case of a shortfall add it to the new budget). Any shortfall would be made up by newly budgeted funds. Any surplus would reduce new budget requirements.

If this system were adopted, agencies would submit their projected requirements to DCA, which in turn would estimate expected prices for service and return to each agency an estimate of its share of backbone costs. The agency would use these for planning purposes in its budget. During the year, however, DCA would calculate actual prices for the services based on actual costs and actual usage and would bill each agency for its share of the realized backbone costs. A discrepancy at the end of the year between budgeted and actual AUTODIN costs for any agency would either leave it with a surplus to be applied the following year or with a deficit to be added to its new budget and made up immediately after the start of a new billing year.

Such a system would still permit AUTODIN budget projections to be used for planning purposes, but would not allow the accumulation by any agency of funds that could be spent for other purposes. In addition, it would assure that any

difference between projected and actual costs by a single agency are adjusted by that agency and are not simply added to or subtracted from the next year's total backbone costs.

It appears that such a system would take maximum advantage of the industrial fund that DCA manages, permitting the fund to cover the cash flow requirements, while allocating costs in the most efficient manner to users.

V. CONCLUSIONS AND RECOMMENDATIONS

AUTODIN was created primarily to provide communications for crisis situations. Its size was determined by the expected exigencies of possible crises, and the system exists to meet those exigencies. Thus it is not an analogue of a commercial service--it does not have as its main purpose the provision of communications services on a routine basis. Given that the system does exist, it is in the interest of the United States Government that maximum use be made of it in peace time since alternative commercial services require additional outlays of funds. The pricing problem is thus one of allocating costs fairly while encouraging as efficient utilization of the system as possible.

DCA sets rates to recover the expected payments from the CSIF to contractors for services provided to maintain and operate AUTODIN. It is desirable that the rates be perceived as fair by the agencies paying them, and at the same time they should promote efficient utilization of the system. Equity is important because most users have no choice about having the system--by command decision they must participate. Even though all the funds provided are public monies, the realities of administrative management require a recognition that agencies are sensitive to budget charges that in their view "subsidize" other agencies.

Efficiency is constrained not only by this requirement for equity but by the following dilemma: to encourage maximum use of the system, charges should be zero. This can be justified because the cost of connecting an additional access line or of sending an additional message is currently zero. The system

has sufficient capacity to service users without additional outlay for trunk lines or switches. And yet the costs must be covered so there must be charges for connections and traffic. In a sense, AUTODIN is like a public good, since use of the system by one person usually does not affect the benefits it provides to other users. The appropriate price for a pure public good is the value of that good to the user--thus, different prices for different users.

Costs can be identified as separable or common. Separable costs are those for services or functions having truly identified beneficiaries or causers. The costs of that service or function can be charged appropriately to the beneficiaries or causers. Remaining costs are common. These should be allocated in a way that promotes DCA policies.

In the case of AUTODIN there are two blocks of separable costs. Part of the system is the network of trunk lines linking to several switches. These trunk lines benefit only people who send or receive messages using them, so that their cost is appropriately charged only to long distance and overseas users. For reasons to be discussed next, these charges should be based upon some measure of the volume of traffic rather than simply by capability to transmit or receive such messages.

The second block of separable costs are those pertaining to ADUs at the AUTODIN I switches. These provide the user capability to connect to the system, and they represent one area where resources are used simply by establishing a connection to the system. High connectivity fees encourage users to make off-system adjustments to maximize the use of existing connections. While these may be cheaper from the using agency's viewpoint, they are not from the viewpoint of the U.S. Government, since the AUTODIN I system already exists while the off-system adjustments do not. Moreover, the more users on the system, the more it will be utilized. Thus, the argument for low connectivity fees is fairly compelling.

At the same time, connectivity charges must reflect the potential cost of a new user connecting to the system. While it is possible to connect new users now, a zero charge might induce more connections than can be supported. Too, access lines of different speeds require different amounts of memory in the ADU, and efficient use of the system requires that users select the appropriate speed of service. It would not be possible to accommodate all current users if only high-speed lines were used. The exact level at which connectivity fees should be set is not obvious but a useful rule initially is to set the fees so they just recover the cost of the ADU memory units.

The remaining revenue requirements can be met by charging for traffic volume, distance, and precedence. As outlined above, charging for distance should recover at minimum the cost of the linking trunkline network. Charges based upon utilization are a better measure of system worth to the user than is the number of access lines, and would result in a fairer distribution of charges.

It may not be possible through pricing alone to provide the incentives necessary to deal with all the problems seen in the system, in particular, that of backside connectivity.[1] Administrative action may be required to complement any set of rates to ensure that the goals of the system are achieved. An evaluation of these administrative actions can be done better once the responses to a new price structure are known, however.

Regardless of the effects that usage pricing may have on backside connectivity, all subscribers would be in a better position to make the choice between AUTODIN and commercial services if such pricing is adopted. Currently, AUTODIN is not attractive to the small users with relatively little traffic because

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[1]This term refers to the construction of networks by users behind their own message processing equipment in order to avoid paying the high charges for an access line into AUTODIN.

the fixed monthly cost is so high. Revising the tariffs would bring his costs lower to the point where commercial alternatives are far more expensive than AUTODIN. The point is illustrated in Table 9.

Table 9. AUTODIN I/COMMERCIAL COST COMPARISON
TYPICAL MONTHLY SUBSCRIBER COST--NEW TARIFFS

CONUS Message Communications	
AUTODIN I: $175/month	MAILGRAM: $954/month
Overseas Message Communications	
AUTODIN I: $249/month	INTERNATIONAL TELEX: $1,367/month
TOTAL	
AUTODIN I: $424/month	COMMERCIAL: $2,321/month

Although the thrust of our conclusions should now be clear, it is useful to summarize them briefly.

- The main basis for charging should be shifted to utilization, including distance and precedence charges. Utilization of the system is a better measure of the worth of the system to the subscribing agencies, and utilization charges better reflect the cost alternatives to provide the same service. Utilization charges would permit lower connectivity charges, thus reducing the incentive for some off-system adjustments and would assist in providing more accuracy in the rate setting process, as utilization probably can be forecasted better than can connections.
- Rate setting and billing should be coordinated to limit CSIF deficits. Efforts should be made to develop better forecasts of system use so that the rates can be set on the basis of more accurate projections than are currently used.
- DCA should address the issue of acquisition and configuration of off-system equipment and services.

It may be that new policy decisions either by DCA or others in the DoD will be required to assure efficient integration of AUTODIN with other communications activities. Attempting to solve all problems with prices alone may not be successful.

- An integrated charging system should be developed for AUTODIN to include both AUTODIN I and AUTODIN II when in place. This pricing should recognize the interdependency of the two systems. Further consideration should be given to implementing procedures to permit charges in AUTODIN II both for distance and precedence.

APPENDIX A

GLOSSARY

GLOSSARY

ACCESS--Having a direct connection to one or more of the communications systems.

ACCESS LINE--Circuit connecting a subscriber to a DCA switching center.

ADDRESS--The destination of a message or a call in a communications system. Also, to indicate the storage location of information in a data processing system.

AMA--Automatic Message Accounting. Equipment installed in a communications system which automatically records all characteristics of calls or messages that may be necessary to ascribe usage and compute billings to various subscribers or users.

ANALOG COMMUNICATIONS--System of telecommunications employing a nominally continuous electrical signal that varies in frequency, amplitude, etc., in some direct correlation to nonelectric information (e.g., sound, light) impressed on a transducer.

ARPANET--A packet switching network providing data communications service between a number of research and military ADP installations.

ASC--AUTODIN Switching Center.

AUTODIN--Automatic Digital Network. A world-wide secure record computer-controlled, store-and-forward, digital communications network providing record communications service to authorized users. The store and forward stations in the network are referred to as AUTODIN Switching Centers (ASC).

The network is a composite of interconnected ASCs (backbone), plus the access lines and subscriber (terminal) equipment.

AUTOSEVOCOM--Automatic Secure Voice Communications Network.

AUTOVON--Automatic Voice Network. The principal long-haul, non-secure circuit-switched voice communications network within the DCA together with its access lines and subscriber equipment.

AUTOVON ASSISTANCE OPERATOR (AAO)--An operator of a switchboard at a selected AUTOVON switch whose function is to provide operator services such as information, random conferencing, intercepting, call area extension, or precedence upgrade.

BACKBONE--That portion of the DCS which is available to all subscribers for long-haul communications (i.e., switches and interswitch trunks excluding access equipment).

BACKBONE COSTS--Those costs associated with leased switches and interswitch trunks, and operations and maintenance of leased and government-owned switches.

BAUD--Rate of speed at which data are transmitted over a communications line.

BINARY CODING--A numbering system consisting of two digits--"1" and "0"--that represent specific values. Used in digital computers.

BLOCKAGE--Calls that are not completed. When expressed as a percentage, blockage equals the call overflow divided by call attempts (OVF/ATT).

CALL--An attempt by a user or subscriber to obtain a telephone connection.

CALLED STATION--A station (telephone number) to which a call is directed.

CALLING AREA--One of five geographical areas used for distinguishing billing charges: CONUS, Alaska, Europe, Pacific, Caribbean.

CALLING STATION--A station (telephone number) initiating a call.

CAPACITY FACTOR--The ratio of the average load communications traffic to the installed capacity of the equipment that supplies the load.

CARRIER--A telecommunications concern that provides trunkline and switching services between geographical centers. A common carrier is such a concern. It provides these services to the general public at rates and under conditions determined by the Federal Communications Commission (FCC).

CCS--A unit of one hundred call seconds (i.e., 1 hour = $\frac{3600}{100}$ = 36 CCS). Used for measuring traffic loads.

CCSD--Command Communications Service Designator. A DCS circuit identification number.

CENTRAL PROCESSING UNIT (CPU)--The main unit in a computer system which processes data.

CHANNEL--An electrical path suitable for the transmission of communications between two or more points, ordinarily between two or more stations.

CHANNEL PACKING--The use of high-speed (9.6 kilobits per second (KBS) or 9600 b/s) modems and time division multiplex (TDM) to accommodate a variety of low- and medium-speed data requirements. The TDM equipment combines several lower speed (4800 b/s or less) data inputs into a single 9.6 KBS data stream. The modems are used to convert the 9.6 KBS data output of the TDM into a quasi-analog signal so it can be applied to a voice-frequency (VF) circuit.

CIRCUIT--A fully operative communications path established in the normal circuit layout and currently used for message telephone, WATS, YWX or private line services.

CLASSMARK--An identification code assigned to subscribers and contained within switch memory for the purpose of switching machine control of calling features.

COMM CENTER--A terminal or relay center processing record message traffic and long distance teletypewriter circuits.

COMMON USER CIRCUIT/SYSTEM--A circuit/system designed for general access.

COMPUTER HARDWARE--Physical components of a computer.

COMPUTER SOFTWARE--Computer program instructions which tell the computer what to do.

COMSEC--Crypto section. Its primary function is to code/decode communications circuits entering and exiting the station.

CONFERENCE CALL--A call in which more than two subscribers are connected. Specific types of conference calls are:

Meet-Me Conference:	An arrangement where each participant is instructed to dial a designated telephone address to reach the conference bridge for a scheduled conference.
Preset Conference:	An AUTOVON feature which permits automatic connection of a group of subscribers, preset in switch memory, by keying a single directory number.
Random Conference:	An operator-established conference where the called participants are manually entered into the conference by the operator.

CSIF--Communications Services Industrial Fund.

DCA--Defense Communications Agency.

DECCO--Defense Commercial Communications Office.

DEFENSE COMMUNICATIONS SYSTEM (DCS)--The primary DoD portion of the NCS, comprised of DoD communications systems and managed by DCA.

DEMAND--(a) Amount of a good that buyers are willing to buy at each specified price in a given market at a given time (demand schedule); and (b) sometimes "quantity demanded" at one specified price.

DEMULTIPLEX--Separation of multiplexed circuits at the receive end.

DUAL SWITCHING EQUIPMENT--Switching equipment actuated by electrical impulses generated by a dial or key pulsing arrangement.

DIGITAL COMMUNICATIONS--System of telecommunications employing a nominally discontinuous signal (discrete values) that changes in frequency, amplitude, or polarity.

DIVERSITY FACTOR--The ratio of the noncoincident maximum demands for service of all customers in a group to maximum demand of that group.

DSTE--Digital Subscriber Terminal Equipment. Government-owned ADPE used by AUTODIN subscriber terminals.

DUAL HOMING--The connection of a terminal so that it is served by two switching centers.

ELASTICITY OF DEMAND OR SUPPLY--A measure of the responsiveness of buyers or sellers to price changes. Defined as the change in quantity demanded (or supplied) relative to a change in price. Let p = price, q = quantity demanded or supplied, then elasticity, $e = \pm \frac{dq}{dp} \cdot \frac{p}{q}$. Elasticity will have a negative sign for demand and positive for supply.

ERLANG--36 CCS; equal to maximum time occupancy of transmission facility for an hour.

FACSIMILE TRANSMISSION--In telecommunications, the capability to transmit pictorial copies electronically.

FDM--Frequency Division Multiplex.

FIXED COST--Cost that does not vary according to output.

FLASH--A communications precedence. (See Precedence.)

FLASH OVERRIDE--The highest communications precedence. Reserved for the President, Secretary of Defense, Joint Chiefs of Staff, and authorized commands.

FREQUENCY--The number of complete sine waves in one second.

FREQUENCY SPECTRUM--Range of frequencies ranging from lowest measurable sound through infinity (Hz, KHz, MHz, GHz, etc.).

GATEWAY SWITCH--Switching center interconnecting geographical areas or networks within a geographical area.

GRADE OF SERVICE--The mathematical probability of a call being blocked, expressed as a decimal fraction. The average ratio of blocked calls to total calls. For example, a GOS of P.05 means that 5 of 100 attempts will be blocked or not completed. GOS objectives set by DCA are observed only through the backbone facilities.

HALF DUPLEX--Send and receive, but not simultaneously.

HF--High Frequency Radio (3-30 MHz) normally used for long-haul communications, provides a means for remote subscriber terminals to access an ASC.

HOLDING TIME--The time in which an item of telephone plant is in actual use either by a customer or an operator. For example, on a completed telephone call, holding time includes conversation time as well as other time in use. At local dial offices any measured minutes which result from other than customer attempts to place calls (as evidenced by the dialing of at least one digit) are not treated as holding time.

IDA--Institute for Defense Analyses.

IMMEDIATE--A communications precedence.

INTRA-SWITCH CALL--A call where the calling and called party are served by the same switch.

INTERFERENCE--Extraneous signals which interfere with communications commonly caused by lightening, power tools, electricity, human voice, extraneous conversations, and electrical components. Examples: static, humm, crosstalk, random noise.

INTERSWITCH CALL--One that uses more than one switch and at least one IST to complete a connection.

INTERSWITCH TRUNK--A trunk between two switching centers (AUTOVON, AUTODIN).

LINE BLOCK--A record length equivalent to one IBM keypunch card, i.e., 80 characters of text plus four framing control characters.

LINE NUMBER--Station number, main station number, subscriber number, user number.

LOAD FACTOR--The ratio of average output to peak output for a given interval of time. Basis for price differentiation between different classes of customers: the lower the load factor, the higher the rate charged the customer.

LOCAL OFFICE--A central office serving primarily as a place of termination for subscriber lines and for providing telephones to the subscribers on these lines.

LONG-HAUL TOLL TRAFFIC--A general term applied to message toll traffic between distant points. In common usage, this term is ordinarily applied to message toll traffic between points more than 20 to 50 miles apart.

MARGINAL COST (REVENUE)--The cost (revenue) which occurs on the margin; the additional cost (revenue) resulting from an incremental change in production (consumption). Marginal cost (revenue) can be described as the instantaneous rate of change in cost (revenue) with respect to production.

MESSAGE--A completed call, i.e., a communication in which a conversation or exchange of information took place between the calling and called parties.

MESSAGE PRECEDENCE--A predetermined coding used to indicate the relative importance of a message. These codes are:

Z for FLASH

O for Immediate

P for Priority

R for Routine.

MESSAGE UNIT--Unit of measurement used for charging for measured message (telephone or digital) exchange traffic within a specified area.

MICROWAVE BROADCAST--A primary transmission medium, the line-of-sight microwave system uses wideband communications to link distant stations. Often substitutes for land lines.

MULTIPLEXING--The technique of combining two or more independent circuits (voice, telegraph, data, etc.) into a composite signal which is then transmitted via the transmission medium to a like terminal where the process is reversed and the channels are restored to their original state.

NETWORK CONTROL--The continuous assessment of the condition of a communications system to detect actual or impending problems and to take subsequent control actions.

NCS--National Communications System.

NMCC--National Military Command Center.

OFF-HOOK SERVICE--A service for selected AUTOVON subscribers that automatically establishes a predesignated connection at the time the calling subscriber's line goes to the off-hook condition.

OPPORTUNITY COST--Implicit cost of a foregone alternative.

OPTICAL CHARACTER READER (OCR)--Device that reads a typed message and automatically generates a printed message for transmission.

PACKET--A number of bits preceded by a header identifying the recipient and transmitted via a communications network. Messages are decomposed into one or more packets by the sender, while the recipient rebuilds the message from the packets.

PACKET-SWITCHING--There are two basic characteristics of a packet-switching communications system. First, all messages are broken down into packets, and it is only these packets that are handled by the system. Second, the packets travel through a common pipeline between switches, and the path any given packet takes from one switch to another is not fixed. Thus, while two users connected through a packet switching believe they have a direct circuit connecting them, this circuit is created anew for each packet.

PEAK LOAD--The size of the maximum demand for service during a given time interval. The period during which message traffic is greatest over a cycle would be the "peak period" as in the "peak hour" for a given day of the week.

POINT-TO-POINT CIRCUIT/SYSTEM--A special purpose circuit or system with predetermined users that is not intended for general purpose use. It cannot be accessed by any other station except the prescribed users. Often referred to as "Sole User," "Hotline," or "dedicated circuit."

PRECEDENCE--A rank assigned to indicate the degree of preference or importance to be given in processing and protecting calls or messages. In descending order of preemption capability, authorized precedences are: flash, immediate, priority, routine.

PRECEDENCE PREEMPTION--To disconnect (either manually or automatically) a connection of lower precedence by seizure of an access line or trunk when there is no other line available.

PRIORITY--A communications precedence.

PRIVATE BRANCH EXCHANGE (PBX)--A switching system that provides internal switched telephone communications between main stations located within a particular area such as a building or a post, camp, or station. It also provides the same service between the main stations and an exterior telephone network. When calls are made without operator assistance (dial service), it is called a PABX (private automatic branch exchange).

PRIVATE LINE SERVICE--A service for communications between specified locations for a continuous period or for regularly recurring periods at stated hours.

PUBLIC GOOD--Goods (or services) jointly supplied to the whole community; typically not appropriable by individuals and not divisible into units to be sold separately. For example, national defense, police and other protection activities provide benefits that cannot be withheld from some individuals and granted to others.

QUEUE--In a store-and-forward, message-switching system, messages awaiting transmission.

RECORD COMMUNICATIONS--Any form of communications that results in recording of information for display, printing.

ROUTINE INDICATOR--In message-switching networks, a group of characters in the header of a message defining the origin or destination circuit/terminal. The indicators are validated by an ASC's internal routing indicator tables for routing traffic.

SATELLITES--Transmission media employing low-power communications satellites in a near-synchronous equatorial orbit.

SIMPLEX--Send or receive, but not both.

SPEED OF SERVICE--The handling time of a message from the origin to the destination terminal.

STORE AND FORWARD--Any system that receives, stores, and transmits data to a predetermined addressee.

SUBSCRIBER--User of a communications system who is directly connected to a switch and shares the network backbone costs.

SUPPLY--(a) Amount of a good that sellers are ready to sell at each specified price in a given market at a given time (supply schedule); and (b) sometimes "quantity forthcoming" at one specified price.

SURVIVABILITY--The capability of a communications system to provide service to the surviving critical subscribers during a disaster which renders some facilities inoperative.

SWITCH--A device for making, breaking, or changing the connections in an electronic circuit. An automatic switch is remote-controlled and is used for voice or digital circuits.

SWITCHBOARD--An apparatus for connecting, combining, measuring, or protecting a number of circuits.

SWITCHING--Circuit switching interconnects communication circuits, providing subscribers with end-to-end voice or data exchanges. Message switching performs automatic relay of messages from one circuit to another on a first-in, first-out (FIFO) basis within each precedence level. Packet switching provides the automatic relay of messages in the multiplexed form of 'packet' streams.

TANDEM CIRCUIT OR TRUNK--A general classification of circuits or trunks between a tandem central office unit and any other central office or switchboard.

TECHNICAL CONTROL--A facility responsible for coordination, control, and operation of DCS resources to include testing and restoral.

TERMINALS--Peripheral devices for transmission and reception of messages.

TOLL TRUNK--A very high quality trunk between long distance switchboards.

TRAFFIC UNIT--A unit of measurement of traffic operating work that is used as the common denominator to express the relative time required for handling various kinds of calls or work functions.

TRANSMISSION MEDIA--The means of moving a signal from one point to another. Examples: HF, coaxial cable, microwave broadcast, satellite, tropospheric scatter.

TROPOSPHERIC SCATTER--Radio system in which the transmitted signal is "bounced" off the tropospheric layers of the atmosphere and received by a distant station.

TRUNK--A transmission channel between switching centers for making a complete circuit between subscribers.

TRUNK NUMBER--A trunk identification number.

USER--An authorized unit possessing communications equipment capable of indirectly accessing a DCS network.

UTILIZATION FACTOR--The ratio of the peak load communications traffic to the installed capacity of the network.

VARIABLE COSTS--Costs that vary with the rate of production.

VFCT EQUIPMENT--A type of multiplexing equipment that converts direct current telegraph signals, as found in teletypewriter (TTY) operation, into alternative current tones in the voice frequency (VF) range.

WIRE TRANSMISSION--A transmission medium employing a physical wire conductor.

WWMCCS--World Wide Military Command and Control System.